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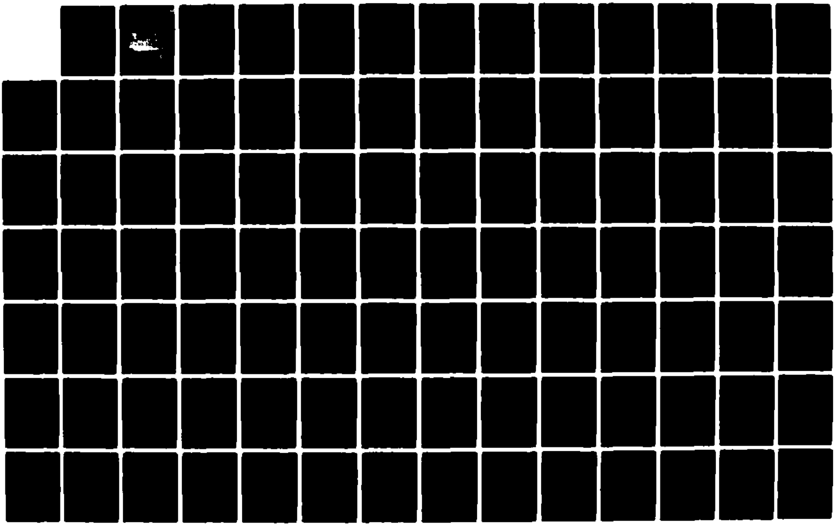

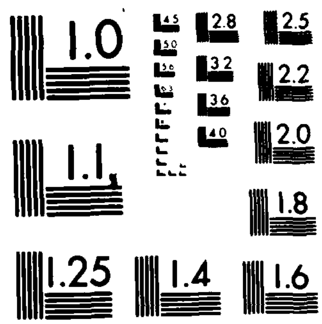

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OCTOBER TO DECEMBER 1983 VOL. 8, NO.4

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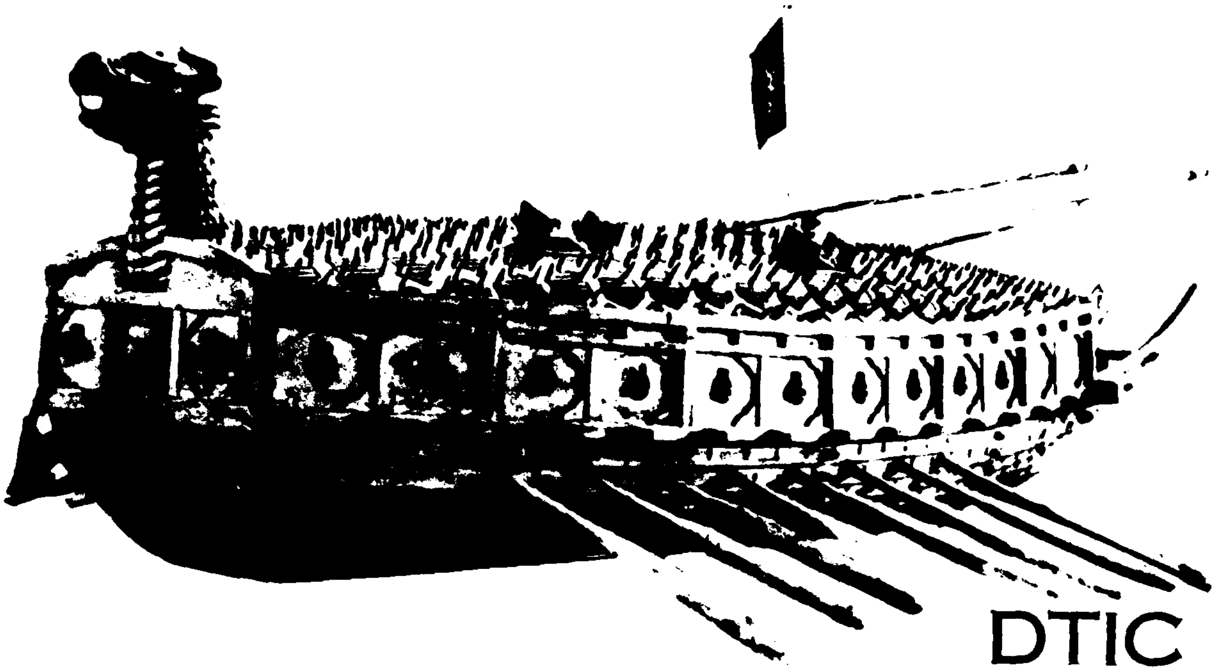
SCIENTIFIC BULLETIN

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH FAR EAST



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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ONRFE Vol 8, ~~Vol~~ No. 4	2. GOVT ACCESSION NO. AD-A138 184	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ONR FAR EAST SCIENTIFIC BULLETIN		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Sachio Yamamoto, Director Mary Lou Moore, Assistant Editor		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Naval Research Liaison Office, Far East APO San Francisco 96503		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE October-December 1983 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Toshiba	Chloroaluminates
Electronics	Cryolite
High voltage	Electrochemical Society of Japan
High power research and development	Molten salts
Japan	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East,

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S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. Key Words (continued)

Molten salt chemistry
Japan
Isotope separation
Countercurrent electromigration
Chemla Effect
Industrial health
Occupational diseases
Japan
Minamata's Disease
National Institute for Industrial Health
Metal powder
Ceramic powder
Government-sponsored research
Japan
Powder metallurgy
Metallurgy research in China
Ferrous industry
Polymers
Nonferrous metals
Export/import commodities
Chinese economy
Ship hydrodynamics research
Korean shipbuilding
Japanese shipbuilding
Naval architecture
Stability 82 Conference
Progress in robotics
Robot Exposition
Robot technology
Crawlers
Sensors
Manipulators

20. Abstract (continued)

with certain reports also being contributed by visiting stateside scientists. Occasionally a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

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CONTENTS

Cover: The "turtleboat" was part of the Korean Fleet during the latter part of the Chosun Period (1392-1910). The turtleboat origins can be traced to the turn of the 15th century. It has still not been determined whether of not the deck was iron-clad; it was apparently covered with iron spikes to repel enemy boarding attempts. Cannon could fired through the mouth of the dragon. According to records, the total length was 64.8 feet, width at the bow was 12 feet, midships 14.5 feet, and at the stern 10.6 feet. Each side of the ship had 10 oars with 22 gunports and 12 doors. On top of the deck were 24 gunports; a flag with the word "turtle" in Chinese Kanji was flown. The ship had a total of 24 cabins. The picture has been reproduced here through the courtesy of the Hanjin Publishing Company of Seoul, Korea, publishers of the book, *Admiral Yi Sun-shin and His Turtleboat Armada,* by Park Yune-hee.

HIGH VOLTAGE AND HIGH POWER RESEARCH AND DEVELOPMENT AT THE TOSHIBA CORPORATION: ACTIVITIES AT THE TOSHIBA RESEARCH AND DEVELOPMENT CENTER

Leon H. Fisher

INTRODUCTION

This report describes the high voltage and high power research and development activities at the Toshiba Corporation and gives a summary of the work being carried out at the Research and Development Center of the Corporation.

THE TOSHIBA CORPORATION

The Toshiba Corporation is a giant integrated electric and electronic products manufacturer. Its real name is the Tokyo Shibaura Electric Company, but it is commonly referred to as "Toshiba." Toshiba is an acroynym formed from the words Tokyo and Shibaura (Shibaura is a district of Tokyo). (Similarly, Tokyo Daigaku or Tokyo University, is universally referred to as "Todai.") Toshiba was formed in 1939 by the amalgamation of Shibaura Seisakusho (Shibaura Manufacturing), a heavy-duty electric manufacturer with a history dating back to 1875, and the Tokyo Electric Company, a manufacturer of such items as induction motors and lamps, which was founded about eighty years ago with the assistance of the General Electric Company. Toshiba considers itself to have been founded in 1875.

The Toshiba Corporation has 103,000 employees. Annual sales amount to about $10.0 billion with profits of about 1.8% of sales. General Electric owns 8.41% of Toshiba's stock just as Westinghouse Electric owns about 10% of Mitsubishi Electric's stock. American ownership of part of Toshiba and Mitsubishi existed before and during World War II. Toshiba expends 4% of total sales on research and development, i.e., about $400.0 million annually.

ORGANIZATION OF RESEARCH AND DEVELOPMENT AT TOSHIBA

Operations at Toshiba are divided into five profit centers. The four largest are designated as "business sectors" and the remaining one is designated as a "group." There are seven "works" laboratories and each is associated with one of the four business sectors. Each works laboratory obtains its operating funds from the business sector with which it is associated. The activities in the works laboratories are applied and product-oriented. The research and development carried out in the works laboratories is considered "near term" and is planned for completion in three years.

The four business sectors and the works laboratories associated with them are:

Industrial Electronics Business Sector

Medical Engineering Laboratory

(Toshiba is Japan's largest and the world's fourth largest electrical medical equipment manufacturer; Toshiba has recently developed a new whole-body computer tomography (CT) imaging system based on nuclear magnetic resonance (NMR) that makes possible accurate diagnoses of many diseases including cancer; this NMR-CT was developed as a joint effort by Toshiba

and Tokyo University's Institute of Solid State Physics; the device was scheduled to have been marketed starting in mid-1983 at a cost of about $1.15 million; the main advantage of the system is that there is no radiation hazard.)

Electronic Components Business Sector

Electron Device Engineering Laboratory
Semiconductor Device Engineering Laboratory

Consumer Products Business Sector

Audio-video Products Engineering Laboratory
Major Appliance Products Engineering Laboratory

Heavy-duty Electrical Business Sector

Nuclear Engineering Laboratory
Heavy Apparatus Engineering Laboratory

The present report deals mainly with the activities of the Heavy Apparatus Engineering Laboratory as well as with the Research and Development Center of the corporation. In addition to the seven works laboratories and the Research and Development Center, Toshiba also has a Manufacturing Engineering Laboratory. The Manufacturing Engineering Laboratory carries out research and development on the use of microcomputers and minicomputers in automated manufacturing equipment and systems as well as in laser processing technology for improving processing precision.

- Heavy-duty Electrical Business Sector

The Heavy-duty Electrical Business Sector is organized into groups and divisions as follows:

Nuclear Energy Group
Heavy Apparatus Group
Transportation Equipment Group
Heavy Apparatus Standard Products Division
Instrument and Automation Division

- Heavy Apparatus Group

The Heavy Apparatus Group has five works. Two of the five works constitute the Keihin Product Operations. The names, locations, and principal products of these works follow:

Fuchu Works (the Fuchu Works are in the Western part of Tokyo; the main products are control panels for traffic control and for general industrial use with emphasis on control of electric power by utilities; relays and computers are the bases of these control panels.)

Hamakawasaki Works (a description of the Hamakawasaki Works based on several site visits is given in the next section.)

Mie Works (the Mie Works is located at Mie, near Nagoya; the main products include medium and small-size transformers, induction motors, capacitors, electromagnetic relays and resistors.)

Keihin Products Operations

Tsurumi Works (the main products are nuclear reactor equipment, steam turbine generators, hydraulic turbines, hydraulic turbine generators, dc generators and large dc and ac motors.)

Turbine Works (the main products are steam turbines for thermal and nuclear power stations, gas turbine and condensing equipment.)

(Both works of the Keihin Products Operations are located in the Tsurumi district of Yokohama.)

- Hamakawasaki Works

In 1962, Toshiba established a center for all of its manufacturing activities of power and transmission and substation equipment. This center is the Hamakawasaki Works and is located in Ukishima, a district of the city of Kawasaki. Kawasaki is an industrial city with a population of over a million and is on Tokyo Bay, halfway between Tokyo and Yokohama. The works is located right on Tokyo Bay facilitating the loading on ships of completed heavy electrical apparatus.

The Hamakawasaki Works employs 2000 people and has a floor area of 127,000 square meters. The main products of the works are various kinds of transformers (typical examples are three-phase 1200 MV A 18/525 kV step-up transformers for thermal and nuclear power stations, single phase 500 kV to 275 kV 1500 MV A extra high voltage substation transformers, three-phase 450 MV A 275 kV to 154 kV high voltage substation transformers, three-phase 680 MV A 11 to 500 kV transformers for pumped storage power stations, rectifier transformers for aluminum refining plants, furnace transformers, transformers for 250 kV dc transmission, and 500 kV/12,000 A current transformers), on-load tap changers, SF_6 circuit breakers operating at voltages as high as 550 kV at 12,000 A, MINICLADS (Toshiba's trade name for SF_6-gas insulated switchgear) rated from 66 to 800 kV (current ratings up to 12,000 A at 500 kV) (in 1969, the works produced the first gas insulated switchgear in Japan and now this is one of the work's main products), ZnO surge arresters, various kinds of high voltage bushings and vacuum tubes operating at voltages as high as 72 kV for vacuum switchgear. Vacuum dc circuit breakers for nuclear fusion devices have also been fabricated. Vacuum circuit breaker manufacturing was transferred to the Fuchu Works in 1981.

The 500 kV to 275 kV 1500 MV A single phase step down transformer mentioned above is an autotransformer manufactured for use at the Shinto-korozawa Substation (located in the mountains) of the Tokyo Electric Power Company. It could not be transported in one piece; some transformers are shipped in as many as six sections. Fifty percent of the transformers are exported; most of them are shipped to Australia (I saw a 500 kV on-load tap changing transformer being assembled for Australia), South Africa and South American countries (Toshiba supplies turbines and generators to Brazil which has the largest hydroelectric station in the world; the rotor diameter of one of the water turbine generators is 14 meters). Two hundred and two (202) 500 kV transformers had been delivered in the ten years previous to my visit for a total capacity of 70,000 MV A. About 1300 power transformers with a combined capacity of 213,000 MV A were delivered during the same period.

Up to a few years ago, Toshiba produced air blast circuit breakers under a license from the Swiss firm, Brown Boveri, but now Toshiba has developed its own SF_6 circuit breakers. (Tank-type oil circuit breakers are still popular in the U.S. and porcelain-type oil circuit breakers are still widely used in Europe.) Japan has pioneered in the development of circuit breakers which open in a single cycle.

Toshiba MINICLADS have been installed in about 8% of Japan's conventional substations (they have been installed in more than 200 power stations and substations). SF_6 is noninflammable and, moreover, the high dielectric strength of SF_6 allows MINICLADS to be compact. They are used in underground stations and can be installed in the basement of a small building. Many MINICLADS are installed around Tokyo. These devices are especially useful under adverse environmental conditions in which salt is present. For this reason, Arab countries prefer the SF_6 system, and of the 30 to 40% of these systems which Toshiba exports, the majority go to Arab countries. I saw a 72 kV MINICLAD in the final MINICLAD assembly shop and also visited the dust-free assembly room for MINICLAD components. (Dust-free rooms are very common in Japanese factories. Workers take off their street shoes and wear protective clothing. Japanese research laboratories in industry and universities often require the removal of street shoes and donning of slippers before entering an experimental facility.) MINICLAD assembly defects are detected by measuring either corona currents or by detecting ultrasonic sound when subjected to high voltage. If defects are detected, the device is disassembled. (It is generally agreed that quality assurance is a very important factor in Japan's economic success.) There is also a dust-controlled shop for transformer coil assembly.

Conventional surge arresters are composed of spark gaps and nonlinear resistors. Up to two or three years ago, Toshiba used series gaps in its surge arresters but now they have changed over completely to ZnO surge arresters. The use of gapless ZnO surge arresters allows a reduction in size by half over the conventional SiC surge arrester and allows the size of MINICLADS to be small. In January 1982, Toshiba introduced what it considers to be the most advanced arrester production line in the world. This line automatically carries out all stages of manufacture including production of elements ranging from 3 kV distribution arresters to 800 kV station-type arresters, extending to complete assembly and final testing of all units.

Toshiba obtains its porcelain from the NGK Insulators Corporation, a Japanese company. NGK produces porcelain as long as twelve meters for Toshiba. (In visiting laboratories and plants in Japan over a period of three years, I have often asked where ancillary products and equipment and instruments being used are manufactured, and the answer was almost always identical, "In Japan, of course.")

I toured the Welding Shop as well as the Switchgear Shop, the Transformer Assembly Shop, the Dust-controlled Shop for Transformer Coil Assembly and the Surge Arrester Assembly Shop. There are a large number of showrooms displaying descriptions and photographs of exported products. The showrooms are designated by countries such as, for example, "The Spanish Show Room."

The Hamakawasaki Works also has an overseas production facility, Toshiba do Brasil S. A. Minas Works, which manufactures middle-size transformers and distribution systems.

- Heavy Apparatus Engineering I boratory

As has already been mentior ., the Heavy Apparatus Engineering Laboratory (it

will be referred to as HAEL in this paper) is under the purview of the Heavy Duty Electrical Business Sector. Specifically, HAEL is associated with the Heavy Apparatus Group within the Heavy Duty Electrical Business Sector. HAEL is divided into four parts, one for the Fuchu Works, one for the Keihin Products Operations, one for the Mie Works, and one for the Hamakawasaki Works. The four parts of HAEL are located at the works with which they are associated. The headquarters of HAEL is at Tsurumi and the director is Dr. Yasuo Miki. The greatest part of the high voltage and high power research and development at Toshiba is carried out in the part of HAEL located at the Hamakawasaki Works. (We will refer to this part of HAEL as Hamakawasaki HAEL. This work will be described in the next section.) Some high voltage and high power research is also carried out at the R&D Center, some of it in cooperation with Hamakawasaki HAEL, and this work will be described later in the report.

The organizations within HAEL are:

Electrical Insulating Technique Engineering
Metallurgical Engineering
Wastewater Treatment Engineering
Atomic Power Equipment Engineering
Electrical Machinery Engineering
High Power and High Voltage Engineering
Systems Engineering
Power Electronics Engineering
Reliability Engineering
Hydraulic Machinery Engineering
Pipe Test Laboratory
Manufacturing Engineering

- High Voltage and High Power Research at Hamakawasaki HAEL

As mentioned in the last section, most of the high voltage and high power research and development at Toshiba is carried out at Hamakawasaki HAEL. This section gives a discussion of this work.

Among other facilities, Hamakawasaki HAEL contains a High Power Laboratory and a High Voltage Laboratory which were completed in 1964 and 1971, respectively. Mr. H. Yoshida has been the manager of both the High Power Laboratory and the High Voltage Laboratory for the last three years. Before that he was in charge of quality assurance for all products of the Hamakawasaki Works. Now he is the manager of the Insulating Materials Laboratory. Dr. S. Yanabu has succeeded him as manager of the High Power Laboratory and the High Voltage Laboratory. There are thirty engineers in the High Power Laboratory and twenty-five in the High Voltage Laboratory. The High Power Laboratory is divided into a testing and a research and development section. The High Voltage Laboratory consists of only one section.

The High Power Laboratory conducts short circuit testing, research and development of ac and dc circuit breakers, ZnO lightning arresters, disconnecting switches, transformers, and distribution equipment. It is equipped with two short circuit generators, one rated at 200 MV A and the other at 125/150 MV A. These generators can be used separately or in parallel and short circuit outputs are available with single and three-phase. During my visit, vacuum circuit breakers were being tested at 63 kA at 50 Hz and such tests are possible at unit voltages as high as 300 kV, providing other testing facilities such as a 1.6 MJ capacitor bank is also used. Plans were being made to

increase this capacitor bank capacity to 2.2 MJ. (There is a building dedicated to the testing of vacuum circuit breakers.)

The High Voltage Laboratory concentrates on ac and dc insulation problems, especially of gas insulated switchgear including long-term testing of ultrahigh voltage (UHV) equipment. The laboratory is housed in two buildings, in addition to the one for testing vacuum circuit breakers. One of these buildings is used for extrahigh voltage (EHV) studies, i.e., 500 kV and less. The other building is devoted to UHV and is used for studies at voltages greater than 800 kV, although the equipment can be used for lower voltages. At the present time, 500 kV is the highest voltage being used in Japan for electrical transmission (the first such line operated in 1973), but plans are being made to double this voltage (in Japan) by 1990. (At present, transmission lines in Japan operate at 500 kV, 275 kV, 220 kV, 187 kV, 154 kV, 77 kV and below, all at ac. A maximum voltage of 250 kV is now being used on Japanese dc transmission lines.) The UHV testing facility is a spectacular building with a parabolic dome 43 m in height, 54 m in width and 61 m in depth. The walls are steel sheet and there is fine metal mesh under the floor, making the entire structure a Faraday cage. The main UHV testing facilities consists of a 6000 kV, 640 kJ impulse generator, a 2300 kV ac generator, two 900 kV transformers and one 1400 kV transformer as well as a 100 mA 2 MV dc generator and a 5 mA 750 kV dc generator. The facility thus contains the highest voltage testing set in the world. There is a huge climatic test room capable of producing temperatures from -40°C to 60°C. Equipment exists to produce rain and humidity over a wide range of conditions ranging from high humidity at high temperatures to Arctic conditions.

Some idea of the research and development activities in high voltage and high power research and development at Hamakawasaki HAEL can be obtained in more detail from the titles and summaries of some recent papers. These are now presented under the classifications of

- Gas Circuit Breakers,
- DC Circuit Breakers,
- Oil Insulation,

and a final catchall category of

- Arresters, Disconnecting Switches, Synthetic Tests, etc.

Unless otherwise noted, all authors are from Toshiba.

Gas Circuit Breakers

"Experimental Investigation of Arc Phenomena in SF_6 Puffer Circuit Breakers." A. Kobayashi, S. Yanabu, S. Yamashita and Y. O. Aoki

> A high speed camera was used to photograph arcs in a model SF_6 gas circuit breaker for 50 Hz currents with rms peaks varying from 10 to 50 kA. The breaker had a double-flow nozzle and was designed to operate in the same manner as a commercial puffer circuit breaker. The nozzle throat diameter was 29 mm and the SF_6 gas pressure was 7 atm. The puffer design made it difficult to observe the arcs on the moving contact side of the nozzle and the arcs were observed only in the region between the nozzle throat and the fixed contact. The arcing time could be varied between 0.7 and 0.9 cycles (14 to 18 ms). For all values of peak current, the

arc columns are stable and are symmetrical about the axis at high currents but become turbulent near zero current. At a current peak of 70 kA, the arc diameter at the nozzle throat outlet was 26 mm and did not fill the throat completely. The arc diameter decreases with decreasing peak current and was 12.5 mm at 10 kA (instantaneous) where 10 kA was also the peak current. The diameter of small current arcs become uniform between the nozzle throat and the fixed contact just before the current goes to zero. On the other hand, high current arc diameters at the downstream region remain considerably larger than at the nozzle throat even just below zero current. This observation demonstrates that thermal effects of high current arcs persist in the downstream region even at zero current.

"Analysis of Gas Flow and Opening Characteristics for Puffer-type Gas Circuit Breakers." S. Yanabu, H. Mizoguchi, T. Iwamoto, Y. Ozaki, and Y. Murayama

(In Japanese)

"Gas Pressure of Puffer-type Breaker During Current Interruption." Y. Ozaki, H. Mizoguchi, S. Yanabu, and A. Kobayashi

Calculations of the pressure in the puffer cylinder were calculated and compared with measured values for two arc temperatures, 5000°K and 20,000°K, of a single pressure SF_6 circuit breaker. This required analysis of the mass flow at current interruption. The heat flow per unit area at 20,000°K was found to be twice that at 5000°K. Calculated results agree with expriment.

"New Developments in Design and Testing of Gas Circuit Breakers." Y. Ozaki, E. Haginomori, S. Yanabu, A. Kobayashi, and Y. Yamashita

Schlieren photographs were used to study gas flow after opening of contacts of gas circuit breakers. Improved gas flow led to improved dielectric strength recovery. Other tests developed include measurements of the transient recovery voltage and postarc current near zero current and development of synthetic test circuits and development of environmental tests.

"Measurement of Voltage Distribution Phenomena in SF_6 Single Pressure Circuit Breaker." A. Kobayashi, S. Yanabu, S. Yamashita, S. Tomimuro, and E. Haginomori

A two-break single pressure SF_6 breaker was used to study voltage distribution in the thermal reignition region. Unbalanced voltage distribution phenomena appear in the vicinity of the limit of interruption ability and these effects are associated with the postarc current. The breaker was also tested under conditions of unbalanced voltage distribution and the performance was found to be unaffected.

DC Circuit Breakers

"High DC Current Interrupting Characteristics of Vacuum Circuit Breakers." S. Yanabu, E. Kaneko, T. Tamagawa, S. Soma, and H. Okamura

(In Japanese)

Results are presented for the relation between arcing time (10-40 ms) and rate of change of current with time (80-150 A/μs) as well as the relation between rate of

change of current with time and rate of change of voltage with time (3-10 kV/μs.) Plasma densities were calculated as a function of time (0-100 μs) for currents changing at the rate of 170 to to 1000 A/μs.

"Development of Full-scale High Voltage DC Circuit Breakers." T. Horiuchi, S. Yanabu, T. Tamagawa, S. Nishiwaki, and S. Tomimuro

Investigations were conducted on high voltage dc circuit breakers and a full-scale unit rated at 125 kV-1400 A was constructed and operated successfully. A triggered spark gap discharges a capacitor into a pulse transformer which, in conjunction with a blocking capacitor in series with the secondary of the pulse transformer, reduces the current in the breaking unit to zero. As the breaking unit, either an ac SF_6 gas circuit breaker or a vacuum circuit breaker may be used. The vacuum circuit breaker permits the use of smaller ac blocking and spark triggered discharging capacitors. However, after interrupting currents as large as 1400 A, the gas circuit breaker recovers much more rapidly in insulating ability than does the vacuum circuit breaker. It is suggested that a vacuum circuit breaker can be satisfactory for a low voltage dc circuit breaker, but that a hybrid configuration of the two types is suitable for a high voltage dc circuit breaker. The paper is not clear on the kind of unit tested, but it seems to have been a hybrid circuit breaker. ZnO varistors were used to absorb the energy produced by the large surge voltage produced by the interruption of the current. Tests on a 250 kV 1500 A dc circuit breaker using a series combination of vacuum and gas circuit breakers were being planned.

"Synthetic Test Methods of High Direct Current Circuit Breakers." R. Shimada, K. Tani, H. Kishimoto and S. Tamura (Japan Atomic Energy Research Institute) and T. Tamagawa, S. Yanabu, H. Ikeda, and T. Matsushita

This paper is a joint effort by investigators from the Japan Atomic Energy Research Institute (known as JAERI) and from Toshiba. These studies were carried out in connection with an inductive energy storage system for the JT-60 Tokamak where a dc circuit breaker interrupts the current in an inductor to produce a secondary voltage in the plasma. The interruption current for the JT-60 is 92 kA. Interruption tests of such dc circuit breakers cannot usually be carried out with power supplies actually used in operation and equivalent circuits and power supplies are used. The test method developed used a capacitor bank for a voltage supply and was demonstrated to be equivalent to an operating system. With this test method, a dc circuit breaker with vacuum interrupters was tested up to 130 kA at 44 kV.

"Life Test of a DC Circuit Breaker for the JT-60 Tokamak for Nuclear Fusion Research." R. Shimada, H. Kishimoto, K. Tani, S. Tamura (Japan Atomic Energy Research Institute) and S. Yanabu, H. Ikeda, T. Tamagawa, and T. Sasaki

(In Japanese)

This paper, like the one above, is a joint effort by JAERI and Toshiba.

Vacuum Circuit Breakers

"The Characteristics of Vacuum Arcs with Magnetic Fields Parallel to Its Columns." T. Kaneda, (Tokyo Denki University) and E. Kaneko, S. Yanabu, and H. Ikeda

Copper electrodes of 52 mm diameter and 10 mm spacing were used with one-half cycle of 50 Hz currents of 5 kA and 10 kA rms. The axial magnetic fields were essentially constant in time and measurements were made for fields between 0.02 and 0.2 T. The electrical measurements consisted of observations of the arc voltage at peak applied current as a function of magnetic field strength as well as of observations of the "shield current" (the current in a shunt connected between the insulated chamber wall and the cathode), also as a function of magnetic field. The presence of the shunt did not affect the arc characteristic. The arc voltage for a given peak current decreases with increasing magnetic field, has a minimum and then increases. For 5 kA, the minimum arc voltage is about 33 V and occurs at a magnetic field of about 0.03 T. For 10 kA, the minimum arc voltage is about 40 V, and the minimum occurs at about 0.1 T. The shield current is about 400 A at 0.02 T and decreases sharply with increased magnetic field to about 10 A at about 0.1 T. The relative intensities of neutral Cu lines at 521.8 and 510.5 nm were measured as a function of time, and from these measurements the electron temperature was calculated assuming local thermodynamic equilibrium. The temperatures were calculated for times of about 2 to about 8 ms after the current was applied. The electron temperatures calculated decrease monotonically with time. They are practically independent of magnetic field. The electron temperature at 10 kA was found to be about 8200°K at about 2 ms after current begins and was found to decrease to about 6000°K about 6 ms later. The electron density was calculated from line broadening and was found not to vary with time to any extent and to be almost independent of current and magnetic field. Values of electron densities were obtained between 10^{16} and 10^{17} cm^{-3}. The arc column splits into many fine columns and is spread over the electrodes.

"Novel Electrode Structure of Vacuum Interrupter and Its Practical Application." S. Yanabu, E. Kaneko, H. Okumura, and T. Hiyoshi

Vacuum interrupters were investigated with novel electrode structures which permit the flow of short circuit current through the interrupter to be used for generation of magnetic fields to stabilize the vacuum arc. The authors describe a radial-type electrode which helps in high voltage and high current interruption. The maximum currents capable of being interrupted for these electrodes are much larger than those for spiral electrodes for corresponding separations.

"Vacuum Arc under an Axial Magnetic Field and Its Interrupting Ability." S. Yanabu, S. Souma, T. Tamagawa, S. Yamashita, and T. Tsutsumi

A demonstration of current interruption up to 200 kA was carried out for a vacuum arc stabilized by an axial magnetic field. Measurements were carried out to determine the relations between the gap length and the arc voltage as well as between the nature of the contact material and the arc voltage. Calculations of the diffusion of charged particles in the axial magnetic field and characteristics of the vacuum arc were determined up to several tens of kiloamperes.

"Parallel Interruption of Heavy Direct Current by Vacuum Circuit Breakers." S. Tamura and R. Shimada (Japan Atomic Energy Research Institute) Y. Kito (Nagoya University) and Y. Kanai, H. Koike, H. Ikeda, and S. Yanabu

A dc circuit breaker consisting of an axially oriented magnetic field in "vacuum" was developed which interrupts current up to 130 kA dc under 44 kV dc recovery voltage. The breaker can carry out this operation 4000 times every ten minutes.

The braking mechanism is composed of two series and four parallel vacuum tubes with a current commutation capacitor. The vacuum arc stabilized by an axial magnetic field in each individual tube displays a moderate positive voltage current characteristic resulting in stable current sharing among the parallel tubes throughout the arc period following contact separation.

"Development of High Current DC Circuit Breaker for Large Tokamak Fusion Device." R. Shimada, K. Tani, H. Kishimoto, S. Tamura (Japan Atomic Energy Research Institute) and S. Tanabe, S. Yamashita, H. Ikeda, and T. Sasaki

This device is the same kind described in the previously summarized paper with two vacuum interrupters connected in series and four in parallel.

Oil Insulation

"Problems of Long-term Reliability for UHV Transformer Insulation." T. Yanari, M. Honda, M. Ikeda, Y. Taniguchi, and Y. Ebisawa

This work was motivated by the plans to implement UHV transmission at 1100 kV in Japan in the early 1990s. Efforts have been directed on the development of UHV transformers, especially with regard to the selection of an appropriate dielectric test voltage procedure. This paper describes the results of tests lasting three years on the reliability of insulation withstanding ac stress in models of components of UHV transformers as well as on UHV prototype transformers developed by Toshiba. In addition, the paper describes the triggering of partial discharges due to switching surges superimposed on ac voltages. The tests must assure that normal operating voltage for thirty years will occur and that short duration overvoltages are guarded against. Ten models of turn-to-turn insulation were tested at fields 1.7 to 4.4 times as high as the operating stress for three years and two months without observing any partial discharges. It was concluded that transformer insulation has a threshold field strength below which no partial discharge will ever occur, regardless of how long the voltage is applied. This threshold field strength is greater than 62.5% of the stress at which there is 50% probability for developing a partial discharge under application of a one-minute ac voltage. Results are also given for section-to-section and main gap models as well as on an autotransformer which is a prototype for UHV for connection between 1200 kV and 550 kV lines. This transformer was designed to provide three windings to provide a capacity of 500 MV A. However, only one of the windings had been completed at the time of the test so that the capacity of the prototype transformer was only 500 MV A/3. A new proposal for ac dielectric tests is also described.

"Electric Field Analysis by Combination Method." H. Okubo, M. Ikeda, M. Honda, and T. Yanari

This paper describes the calculation of electric fields with axial symmetry for arrangements of interest in high voltage equipment. The "combination" method is one in which two methods are combined. The two methods are the "charge simulation" method and the "finite element" method. The strong points of each method are employed and their weak points avoided. Results are given for a rod-plane configuration with space charge and for high voltage bushings and the calculations include the effects of leakage resistance.

"Suppression of Static Electrification of Insulating Oil for Large Power Transformers." M. Yasuda and K. Goto (Tokyo Electric Power Company) T. Ishii (Mitsubishi Electric Corporation) E. Mori (Hitachi, Ltd.) M. Masunaga (Nippon Oil Company) and H. Okubo

Insulating oil in large power transformers is forced to circulate to remove the heat generated by losses within the windings and core. This circulation is known to produce "streaming electrification," that is, electrification of the paper and pressboard within the windings. This paper shows that streaming electrification is associated with degradation of oil under longtime operation of the transformers. Certain substances have been found to reduce the degradation. Two substances mentioned in the paper which accomplish this are alkylbenzene and 1,2,3-benzotriazol. In general, the pumped oil after contacting the surface of solid insulating materials becomes positively charged. The paper describes experiments in which insulating oil were first degassed and then had added to them the amount of oxygen gas normally present in transformers and then were subjected to thermal tests and charging experiments. Under heating, ordinary mineral insulation oil shows degradation with time in its ability to withstand charging, its resistivity drops with time and the dielectric loss tangent increases with time. In this case, the oil was heated to 110°C and contained 10 ml of oxygen per 100 ml of oil. The degradation effects saturated in 48 hours.

"Short Time AC V-t Characteristics of Oil Gaps." T. Harada, Y. Aihara (Central Research Institute of Electric Power Industry), T. Kawamura, (University of Tokyo), S. Kumagai, (Takaoka Electric Manufacturing Company), Y. Inoue (Nisshin Electric Company), Y. Kamata, (Hitachi Ltd.), K. Matsuura (Fuji Electric Company, Ltd.), T. Watanabe (Mitsubishi Electric Corporation), T. Sugimoto (Meidensha Electric Manufacturing Company, Ltd.) and M. Murano and M. Ikeda

This paper reports the measurement of the time necessary for breakdown to occur as a function of applied ac voltage for a standardized gap filled with a standard insulation oil. The work was carried out cooperatively by workers from the organizations listed above as well as by Toshiba. The authors are members of the High Voltage Testing Committee of the Institute of Electrical Engineers of Japan. Seven Japanese transformer manufacturers cooperated in the study. The standardized gap consisted of brass electrodes of 105 mm diameter and separation of 7.5 mm. The oil was the No. 2 Insulation Oil standardized by Japan. After suitable filtering and reduction of water and gas contents to less than 10 ppm and 1% respectively, and then waiting for 48 hours, the breakdown voltage-time studies were carried out. The current was limited by either a current-limiting resistor or by a reactor in series with the test transformer. The voltage was raised linearly to the value to be studied and then the time for a breakdown to occur at this voltage was measured. If breakdown did not occur in 20 minutes, the test was concluded and another voltage was applied. The resulting data was analyzed statistically to obtain a more reasonable procedure for on-site testing of 500 kV transmission equipment. (In Japan, it is normal practice for every piece of power transmission equipment to be subjected to a ten minute on-site voltage test.)

"Partial Discharge and Breakdown Probability Distribution and Equi-Probabilistic V-t Characteristics of Oil-filled Transformer Insulation." M. Ikeda, T. Yanari, and H. Okubo

Probability distributions for partial discharge and for dielectric breakdown voltages were studied for typical components of oil-filled transformer insulation in the time range from microseconds to ten hours. The studies were made for

lightning impulses and for ac voltages. The impulse ratio for lightning impulses ranges from 1.37 to 1.62 for the inception of partial discharge and ranges from 1.74 to 2.5 for breakdown. The inception of partial discharge for a lightning impulse voltage occurs at 55 to 65% of the one-minute ac voltage onset for partial discharge. Studies were also made with switching impulses and the inception of partial discharge and breakdown occurs at 85 to 92% of the voltages for which these phenomena occur with lightning impulse.

"Breakdown Characteristics of Moving Transformer Oil." M. Ikeda, T. Teranishi, M. Honda, and T. Yanari

The authors decided to investigate the breakdown characteristics of moving transformer oil since many EHV large-capacity power transformers use a forced oil cooling system. The work showed that the breakdown voltage (both ac and dc) for moving oil is higher than that for stationary oil by 10 to 15% at a velocity of 5 cm/s. At 25 cm/s, the breakdown potentials are about the same. At 100 cm/s, the breakdown potential for moving oil is 90% of that for stationary oil. However, under impulse voltages the breakdown is identical for moving and stationary oil. In these experiments, the oil contained the same concentration of impurities. The impurities were monitored optically. It was concluded that impurities in oil of UHV voltage transformers should be reduced and that the impurity level of the oil should be monitored optically.

"Statistical and Experimental Study Relating to the Dielectric Breakdown of Transformer Oil." M. Murano, S. Menju, M. Ikeda, and N. Hasegawa

This paper is a theoretical and experimental investigation of breakdown of transformer oil from the point of view of "volume theory." This theory, which is 30 years old, introduced the concept of stressed oil volume. In a uniform field, the stressed oil volume is identical to the real oil volume, but in a nonuniform field the volume of oil in the part of the field which is higher than 90% of the average potential gradient. According to these ideas, the predominant factor in determining the breakdown of oil is the floating impurities which exist in technically refined oil. A statistical analysis of the breakdown of oil in uniform fields is based on the assumption that each unit of oil volume has the same breakdown probability since there is the same probability of a microscopic defect in the oil. Analysis was carried out for uniform fields and extended to nonuniform fields. Experimental tests were made in a 1200 liter tank of oil with oil that had been processed in the same method as is used for power transformers. One electrode configuration was a hemispherically-tipped rod to plane electrode with small oil volume range from 3×10^{-7} to 6×10^{-4} cm^3. The other configuration is a large plane to plane electrode system for large oil volume range of 5.0×10^5 to 10^6 cm^3. Results are analyzed for the various volume ranges in terms of the volume theory. It was found to hold in the volume range studied prior to this work of 3×10^{-2} to 4×10^4 cm^3, but deviations were found both below and above this range.

Arresters, Disconnecting Switches, Synthetic Tests, etc.

"High Current Interruption by SF_6 Disconnecting Switches in Gas Insulated Switchgear." S. Yanabu, S. Nishiwaki, A. Mizoguchi, N. Shimogawara, and Y. Murayama

This paper is concerned with disconnecting switches operating in SF_6 gas used for interrupting currents in gas insulated switchgear. These currents are known as loop currents since the line current is forced to travel in two parallel loops through closed disconnecting switches in each loop. The switching of current to gas insulated bus lines requires the opening of a disconnecting switch. These disconnecting switches are right in the gas insulated switchgear and any decomposition products degrade the insulating performance of the gas insulated switchgear. The paper is devoted to a study of how to reduce the arcing time of the disconnecting switch in order to reduce dust production. The currents interrupted are several kiloamperes and in many cases the current must be interrupted frequently. The paper attempts to study the effects of various kinds of electrode structure on the arcing time. Four types of electrodes were studied, a free burning type, a self-blast type, a magnetically driven type and a puffer type. The magnetically driven type and puffer type electrode structures were found to be most effective in reducing the arcing time.

"Study of Switching Surge Duty Characteristics of ZnO Surge Arresters." S. Nishiwaki, T. Sato, S. Kojima, S. Yanabu

(In Japanese)

"Small DC Current Breaking Phenomena of Air Blast Circuit Breaker." S. Yanabu, S. Nishiwaki, H. Ikeda, T. Horiuchi

This paper reports studies regarding the current chopping phenomenon of an air blast circuit breaker with and without an impedance in parallel.

"Switching Surge Operating Duty of HVDC Arresters and Characteristics of Reignition Type Gaps." S. Nishiwaki, T. Sato, S. Kojima, S. Yanabu

(In Japanese)

"An Approach to the Suppression of Sheath Surge Induced by Switching Surges in a Gas Insulated Switchgear/Power Cable Connection System." M. Ishikawa and N. Ohashi (Tokyo Electric Power Company), J. Shinagawa (Showa Electric Wire and Cable Company, Ltd.) and Y. Ogawa, M. Ikeda, and H. Miyamoto

This paper deals with surges induced in the sheath of a SF_6 gas insulated switchgear/power cable connection system. High frequency switching surges generated from the gas insulated switchgear in turn induce sheath surges across insulation sleeves located at gas insulated switch gear/power cable connection points and at cable cross-bonded points. The work was carried out on a large-scale apparatus consisting of a 66 kV gas insulated switchgear and a 300 meter-long power cable. The switching surges generated in the main circuit when the no-load gas insulated switchgear is closed were found to depend on the reflection of pulses in the cylindrical gas insulating switchgear bus. The surges rise sharply and are attenuated in several microseconds with a frequency of several megahertz. The surges induced at the grounding gas insulated switchgear and cable sheaths reach a value as high as 40% of the voltage between the poles of the circuit breaker. Aerial flashover of the insulation sleeve caused by surges induced between sheaths was observed. It was proposed that the insertion of a capacitor between the sheaths provides the most effective suppression of surges at the gas insulated switchgear and cable sheaths. It was found that the sheath surge can be suppressed within acceptable limits even in a 275 kV and higher gas insulated switchgear power cable

connection system. Both the capacitor method and the use of zinc-oxide arresters are effective for the suppression of sheath surges at the cable insulation joint.

"Local Voltage Oscillation in Interleaved Transformer Windings." T. Teranishi, M. Ikeda, M. Honda, and T. Yanari

Interleaved winding is widely used in the high voltage winding of a core-type transformer because of its excellent property of protecting against lightning surges. However, high frequency oscillations occur between sections of the winding when steep impulse waves are present. The interleaved winding is one of the most suitable high voltage windings for UHV transformers. At UHV, since the higher the voltage, the larger the number of turn per section of the windings, the interleaved windings will have large local oscillations. This paper describes measurements of the local oscillation produced for six different types of windings. The effects of the number of sections on the maximum voltage between sections were studied using a low voltage impulse generator. The effects of the rise time of the pulse were also studied with the rise times varying from 0.2 to 1 μs. Two kinds of windings were investigated, the conventional Stearn winding and the Nuys winding. Each of the models studied had an inside diameter of 900 mm, a spacing of 5.6 mm between sections and a 1 mm thick insulation between turns. For the Stearn winding, having 30 turns per section, it was found that the maximum voltage between sections was less when there were two sections than when there were six and 20 sections. There was little difference between the six and the 20 section models.

Some of the people I met in connection with my visits to Toshiba's high power and high voltage activities are:

Mr. Hisatoshi Ikeda, High Power Laboratory
Dr. Yoshihiro Kawaguchi, Chief Managing Engineer, Hamakawasaki Works
Dr. Mitsuyoshi Yamamoto, General Manager, HAEL
Dr. Satoro Yanabu, Manager, High Power Laboratory and High Voltage Laboratories
Mr. H. Yoshida, Manager, Insulating Materials Laboratory

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Tsurumi-ku
Yokohama, Japan

TOSHIBA RESEARCH AND DEVELOPMENT CENTER

As mentioned earlier, in addition to its seven works laboratories and its Manufacturing Engineering Laboratory, Toshiba has a Research and Development Center.

About 10% of the budget of the Center is obtained from government agencies such as the Ministry of International Trade and Industry (MITI) and from a new government energy foundation. (The MITI work is scheduled for eight to ten years.) About 45% of the remaining budget is provided directly by corporate headquarters without being funneled through the profit centers (these give rise to what are known as sustaining programs) and the remaining 55% is supplied by the profit centers (known as commissioned programs). The Center carries out long-range research and development looking ahead five to ten years. The activities involve both basic research and work on new products, but the Center does not carry new products through to production. The Center has about 1500 employees and has 70,000 square meters of floor space. It is, with the exception of one activity, located in one place in Kawasaki. Dr. Kiyoshi Nagai is the director of the Center.

Meetings of Center personnel are held twice a year with the heads of the profit centers and with the managers of the works laboratories. The Center publishes about 1000 papers a year; 50 to 100 papers are presented in English at international meetings. The Center accounts for about 2500 of the 20,000 patents which Toshiba files annually with the Japanese Patent Office. The R and D Center files about 500 patents overseas annually.

Plans for work in the Center proceed both from the top down and from the bottom up (the seeking of a consensus of all parties concerned in a problem is often given as one of the reasons for Japan's success in technology and in business and in government planning). Every researcher turns in a proposal for what he wants to do to a planning committee. Dr. Nagai has stated, "... if we are to expect original technologies of our researchers, the management strategy should be such that will put a premium on the enthusiasm and willingness of the researchers to do what they really want to do." Even though plans are made for five to ten years ahead, projects are reevaluated every year.

The Center consists of laboratories and departments. The departments are more closely associated with product development than are the laboratories. These organizations and some of their activities follow:

Metals and Ceramics Laboratory

- High Strength Silicon Nitride Ceramics
- Reactor Material Evaluation by Constant Strain-rate Testing
- Glass Fibers for Optical Communication
- Vitrification of High-level Radioactive Waste
- Amorphous Metals

Chemicals Laboratory

- Synthesis of Polymers
  (development of heat resistant polymers, epoxy and alkyd premixed molding compounds.)
- Thermal Insulation for Refrigerators
- Instantaneous Corrosion Rate Meter
- High Reliability Plating Bath for Printed Circuit Boards
- Biochemical Sensors
  (for detection of bioactive ions and rapid response stable enzyme sensor for glucose with an asymmetric ultrafiltration membrane and immobilized glucose oxidase; I saw a demonstration of the glucose sensor.)

Materials Application Department
(provides consulting and technical services)

Testing Apparatus
(optical, thermal, and mechanical testing of metals, plastics, and ceramics.)
Instrumental Analysis
(includes electron probe microanalysis, EPMA, Auger analyzers and electron microscopes.)

Electron Devices Laboratory

Single Crystal Growth
(computer-controlled automatic pulling system for growth of large diameter GaP and $LiTaO_3$ single crystals.)
Display Panels
(multicolor LED flat panel display with 240 x 320 picture elements.)
CCD (Charge Coupled Device) Image Sensors
Optoelectronics Devices and Semiconductor Sensors
(GaAlAs/GaAs and InGaAsP laser diode and high radiance LEDs have been developed for optical communication and optical disk memories; semiconductor sensors, such as Si pressure sensors, GaAs Hall generators and Si X-ray detectors have been developed.)
High Power GTO (Gate Turn Off) and Light Triggered Thyristor Semiconductor Devices
GaAs Gate Arrays
[work is designed to realize 1000 IC gates at low power using GaAs E-FET (Enhancement-mode Field Effect) transistors; at the time of my visit a 500 gate arrangement had been achieved.]

Integrated Circuits Laboratory

Development of LSI Memories
Plasma Ion Etching Lithography
Electron Beam Lithography

VLSI Application Department

Logic VLSI (CMOS Gate Array, etc.)
Sixteen-bit Microprocessor
[contains more than 7000 gates on a sapphire substrate (work supported by MITI).]

Electronics Equipment Laboratory

Medical Electronics
(real time observation of moving human organs using electronic scanning system of ultrasonic diagnostic equipment.)
Surface-Acoustic-Wave Devices
(development of surface-acoustic-wave color TV IF filter and other components.)
Antennas
(activities range from antennas for satellite communication to consumer antennas; Toshiba will have a new parabolic horn antenna on a satellite to be launched in 1984.)

Information Systems Laboratory

Rapid Image Processing

Optical Chinese Character (Kanji) Reader

[can read more than 2000 Kanji characters printed on ordinary paper at a speed of 100 characters per second (Kanji are Chinese ideographs to which Japanese attach the same meanings as do the Chinese, but give them Japanese vocabulary; this is the only connection between Chinese and Japanese).]

Japanese Word Processor

(the input is one of the two phonetic Japanese sets of symbols, Kana, of Japanese words and these are automatically rewritten in Kanji.)

Polyprocessor Systems

Special Studies Laboratory

Computational Tomography

(mathematical algorithms for image formation and development of special purpose processors for use with Toshiba CT scanners.)

Recording Media and System Development Department

Perpendicular Magnetic Recording Technology

Energy Science and Technology Laboratory

Superconductivity

(helium refrigerator and superconducting magnet for magnetically levitated trains; at the time of my visit to the R and D Center, the Japan National Railway magnetically levitated train had two one-third scale railroad cars, but this was soon to have been increased to three cars; each car has, or is to have, four helium cryostats and two superconducting magnets in each cryostat; these magnets must be light and have a high magnetomotive force and the distance between the on-board superconducting magnets and ground coils must be as small as possible; the eight magnets in the front car and four magnets in the second car were supplied by Toshiba; Toshiba is also supplying four of the eight magnets for the third car and thus is supplying two-thirds of all the superconducting magnets on these three cars; the second car has four magnets supplied by Hitachi and the third car's four magnets were to have been supplied by Mitsubishi Electric; the windings of all magnets are identical and consist of Nb_xTi_y where x is about 30 and y is about 70; the magnets all operate at 4.2°K; the weight of each magnet is 160 kg and produces a magnetomotive force of 800 kA T; other superconducting work at Toshiba includes development of NbTi based ternary superconducting alloys such as NbTiHf to be used for high field magnets cooled by He-II at 1.8°K with critical current density of 1500 A/mm^2 at 10 T, development of superconductors for pulsed magnets to be used in fusion devices at JAERI, development of a 3000 kW superconducting homopolar generator, development of the superconducting wiggler magnet used in the Photon Factory, a dedicated synchrotron radiation facility at the National High Energy Laboratory in Tsukuba Science City, development of a small superconducting cyclotron for Kyoto University and development of an 8 T superconducting magnet for magnetic separation of isotopes.)

Fuel Cell Power Plant Systems
(two systems are being worked on, the one furthest along is one which uses concentrated phosphoric acid as an electrolyte; it uses carbon paper and platinum as a catalyst for both the anode and cathode, the cathode using 0.6 mg/cm^2 and the anode using 0.3 mg/cm^2 of Pt; the present Toshiba phosphoric acid cell uses hydrogen and oxygen as fuel and is contained in a metal cylinder 160 cm in diameter and 2 feet in height; this unit consists of 74 cells in series with each cell having a potential difference of 0.63 V with a total voltage of 47 V and a current of 800 A; theoretically 1.2 V should be developed per cell, but internal resistance reduces the output voltage to 0.63 V; the device operates at 35 kW; at the time of my visit, this fuel cell had operated over 250 hours, but not continuously; a second generation molten carbonate fuel cell would operate at 650°C or higher, but development of this is considered to be ten or twenty years off; the phosphoric acid fuel cell work is being supported by MITI; the other type of fuel cell being pursued, a molten carbonate electrolyte device, is also being supported by MITI; all fuel cell work at Toshiba's R and D Center is being carried out in cooperation with HAEL and the Heavy Apparatus Group of the Heavy Duty Electrical Business Sector; MITI is sponsoring fuel cell work at four large companies, including Hitachi, Mitsubishi Electric, and Toshiba.)

Beam Line Components Including Ion Sources for Neutral Beam Heating of Fusion Plasmas (this work will be described in the next section.)

Automatic Powder Doser for Plutonium Powder
(for use in the analytical laboratory of a plutonium fuel production facility.)

Mechanical Engineering Laboratory

Design of Earthquake-proof Nuclear Power Stations
(this facility has a shaking table 5x5 m which can vibrate horizontally and vertically simultaneously to simulate biaxial earthquake vibrations; the maximum horizontal shaking force is 40 tons and the maximum vertical shaking force is 27 tons; the maximum acceleration for full horizontal load is one g and for full vertical load is 0.67 g; the frequency can be varied from dc up to about 30 Hz; sinusoidal vibrations can also be applied; the shaking table is driven by six hydraulic activators; four are used for the vertical motion and two for the horizontal motion; the amplitude is 75 mm in the horizontal direction and 37.5 mm in the vertical direction; the facility is being used to test fuel assembly and control rods of boiling water reactors.)

Very High Speed Centrifuge for Uranium Enrichment
Improvement in Gas Turbine Blades
Rupture Tests on Nuclear Plant Piping
Acoustical Holography as a Means for Noise Control

Hybrid Functional Circuits Development Department

Electronic Ceramics
High Density Hybrid Modules
Nondestructive Testing Using Ultrasonics

- Research Activities on Electrical Discharges and Related Phenomena at the Research and Development Center

At the time of my visit, a number of presentations were made on electrical discharges and related phenomena because of my own professional interest. For this reason, a section is included under the above title and this work is now discussed. The work, in some cases, was mentioned earlier and of course all of the work to be discussed is carried out in one or more of the organizations mentioned above.

Low Pressure Arc Discharges

High power neutral beam heating of plasmas require pulses of 100 A ion current lasting for 10 s. Cathodes for such ion sources present special problems. The work at Toshiba involves development of various kinds of ion sources and cathodes. Three types of ion sources have been worked on: the DuoPIGatron (developed at Oak Ridge National Laboratory), The LBL (Lawrence Berkeley Laboratory) type and the Bucket (or Mackenzie type). Studies have been made of large area hollow cathodes of LaB_6 and of Mo + La_2O_3 (the Mo is impregnated with La_2O_3). Extensive studies have been carried out of ion and electron currents at the cathode surface in a LaB_6 hollow cathode arc. Axial and radial profiles of plasma parameters were determined inside the cathode. The plasma was hydrogen and a Langmuir probe was used. The plasma density at the cathode surface was between 10 and 20% of the plasma density at the axis. The ion current at the cathode surface was found to be larger than the electron current. The current at the hollow cathode surface consists of thermionic current, ion current, and secondary electron current induced by ion bombardment. Electron bombardment as a method of heating cathodes is being investigated.

Vacuum Arcs

The study of such arcs is being undertaken in connection with the development of high power circuit breakers. In particular, the R and D Center is carrying out basic research on single cathode spot arcs with special reference to current chopping and instability phenomena as well as on the breakdown of postarc plasma sheaths. In another study, an analysis of a stationary copper cathode spot was made of the cathode power dissipation with the aid of measurements by calorimetric means. This allowed evaluation of cathode temperature, current density, fraction of the current carried by electrons, electric field at the cathode surface, spot radius, and sheath voltage. In still another study, electrostatic probe measurements and residual current measurements were made in the plasmas of single spot copper vacuum arcs after forced extinction of the arcs took place. These experimental results were used to estimate the ion velocity distribution as well as the electron velocity distribution.

DC Electrical Breakdown of Liquid Helium

With Toshiba's great interest in superconducting magnets, it is not surprising that studies on dc breakdown of liquid helium are being carried out. In one study, breakdown in liquid helium at 4.2°K was made in moderately uniform fields as a function of gap length (up to 2.0 mm), as a function of first cathode roughness, and then anode roughness. The breakdown potential for rough anode surface varying between 0.3 and 3 μm is independent of roughness, but there is quite a strong dependence on roughness of the cathode. Prebreakdown currents were measured for point to plane electrodes. As the voltage is raised, luminosity appears at the tip of the point and associated with this are currents of about 1 μA and bubbles flow in the liquid. Another study investigated the breakdown characteristics of supercritical helium with nonuniform fields as a function of density.

Mail to the R and D Center may be addressed to:

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Saiwai-ku, Kawasaki 210
Japan

- Additional Note: An Example of Other Toshiba Activities Overseas

As an example of other Toshiba activities overseas, it may be interesting to mention that Toshiba is building and equipping an audio manufacturing plant in the German Democratic Republic. The plant is being constructed at an industrial park on the outskirts of East Berlin and will have an annual production capacity of approximately 750,000 radio cassette recorders and 30,000 hi-fi cassette decks. Shipment of plant equipment is to start in February of 1984.

This will be the third largest industrial plant ordered from Toshiba by the German Democratic Republic. The two larger orders previously received were for a lamp manufacturing plant and a color picture/glass bulb manufacturing plant.

THE FIRST INTERNATIONAL SYMPOSIUM
ON MOLTEN SALT CHEMISTRY AND TECHNOLOGY
AND VISITS TO MOLTEN SALT LABORATORIES IN JAPAN

Gleb Mamantov

INTRODUCTION

In December 1981, I received the first announcement of the First International Symposium on Molten Salt Chemistry and Technology and the invitation to present a plenary lecture at this symposium scheduled for Kyoto on 20-22 April 1983. Although interest in molten salts, ionic media which exist as liquids from subambient temperatures to those in excess of 1000°C, can be traced to the beginning of the nineteenth century, only in the 1950s did the research activity in molten salts begin to accelerate. The first Gordon Conference on Molten Salts was held in 1959. These conferences have been taking place since then on a biannual basis (in recent years as the Conference on Molten Salts and Metals). In the '60s a similar conference, the EUCHEM Conference on Molten Salts, was organized in Europe and has been held every other year in different European countries and even Israel. In 1976, the first International Symposium on Molten Salts organized under the auspices of the Electrochemical Society was held in Washington, D.C. The Fourth International Symposium of this type was held at the Electrochemical Society Meeting in San Francisco in May 1983. This symposium attracted over 70 papers and a large number of both American and foreign participants in spite of the fact that it was held less than a month after the meeting in Kyoto.

This brief summary of international meetings on molten salts points out that the First International Symposium on Molten Salt Chemistry and Technology was not the first international meeting devoted to molten salts. On the other hand, the symposium in Kyoto was probably the first meeting that stressed both the fundamental and the technological aspects of molten salt chemistry. This meeting was probably the largest ever devoted to various aspects of molten salts; it attracted over 300 registered persons from some 20 countries and more than 130 papers (several of these were cancelled when the delegates from the Soviet Union did not attend). Perhaps most importantly, the Kyoto symposium served as a very good overview of the tremendous activity in Japan in the area of molten salts; more than 70 papers came from laboratories in Japan. It is fair to state that, with the possible exception of the Soviet Union, there is more activity in this area in Japan than in any other country.

TECHNICAL SESSION

The Kyoto symposium was held on the 25th anniversary of the Molten Salt Committee of the Electrochemical Society of Japan and the 50th anniversary of the Electrochemical Society of Japan. The symposium papers were placed by the Organizing Committee (chaired by Professor Nobuatsu Watanabe of Kyoto University) in one of the following categories:

- fundamentals,
- chemical processes,
- elelctrolytic processes,
- aluminum production,
- pyrometallurgy,
- energy - conversion and storage,
- others.

The names of the plenary lectures and the titles of their lectures are given below:

Name	Title
Professor H. A. Øye Norwegian Institute of Technology Trondhein, Norway	Thermodynamic properties and models of chloroaluminate melts.
Professor P. Mergault University of Pierre et Marie Curie Paris, France	Electrode effects in some molten salts
Professor G. J. Hills University of Strathclyde Scotland	Electrodeposition of metals from molten salts
Professor M. Chemla University of Pierre et Marie Curie Paris, france	Electrochemical behavior of carbon materials in molten fluoride systems
Professor A. Klemm Max Planck Institute Mainz, West Germany	Isotope enrichment by electromigration in molten salts
Dr. J. *Thonstad* Norwegian Institute of Technology Throndheim, Norway	Moving boundary studies of dissolved metal in molten $CdCl_2$ and $BiCl_3$
Professor B. J. Welch University of Auckland New Zealand	A study of the relationship between the properties of alumina: its interaction with aluminum smelting electrolytes
Professor J. Gerlach Technical University of Berlin German Democratic Republic	Dissolution and interactions between alumina and cryolite melts
Professor A. Mitchell University of British Columbia Vancouver, Canada	Chemistry and heat transfer in in ESR slag.
Professor G. Mamantov University of Tennessee Knoxville, TN	Chemistry and electrochemistry in molten chloroaluminates
Professor H. A. Laitinen University of Florida Gainesville, FL	Mechanism of the sulfur-sulfide electrode reaction in molten LiCl-KCl eutectic
Professor T. El Gammal Technical University of Aachen Federal Republic of Germany	Electrocapillarity between molten salts/ slags and liquid metals

Dr. M. L. Saboungi Argonne National Laboratory Argonne, IL	A molecular dynamics study of complexing in molten salts
Professor B. L. Tremillion University of Pierre et Marie Curié Paris, France	Oxide ion exchange reactions in molten salts: studies by means of a zirconia membrane electrode
Dr. G. Inman Imperial College London, United Kingdom	Voltammetric studies of iron in molten $MgCl_2$-NaCl-KCl. The reduction and oxidation of Fe(II)
Professor T. A. O'Donnell University of Melbourne Victoria, Australia	Anhydrous hydrogen fluoride--a room temperature analog for acidic melts
Dr. G. G. MacPherson Institute for Energy Analysis Oak Ridge, TN	The radiation stability of molten fluoride fuels

Each plenary lecture was allotted 40 minutes; the remaining papers were scheduled for 20 minutes. A poster session included 11 presentations and a demonstration by Professor G. J. Janz, Rensselaer Polytechnic Institute (RPI) Troy, New York, on physical properties data activities of the molten salts data center at RPI.

The oral presentations took place in three concurrent sessions. Such scheduling was unquestionably the weakest aspect of the symposium; on more than one occasion I wanted to attend three papers being presented at the same time. The obvious solution to this problem would have been to extend the symposium to four or five days which, however, would have resulted in higher costs. In all other aspects the organization of this symposium was a model of efficiency. For example, the complete papers, received by the Organizing Committee two months before the meeting, were available as a bound volume at the time of the symposium.

As might be expected, a large number of papers dealt with various aspects of aluminum production and with melts containing aluminum salts, such as chloroaluminates and cryolite. For example, Professor T. Ishikawa of Hokkaido University discussed the evaluation of the bipolar cell for electro-winning of aluminum from chloride melts; this research, although similar in principle to the Alcoa chloride process, involves several differences compared to the Alcoa process, such as a different electrolyte and different electrode configuration. Professor H. Wendt, Institute for Chemical Technology, Darmstadt, West Germany, discussed several aspects of aluminum deposition from high temperature chloroaluminate melts; he advocates the use of cathodes which do not alloy with aluminum, the use of noncarbonaceous anodes, and a separator to limit reoxidation by dissolved chlorine. Current interest in chloroaluminate melts was evident from the plenary lectures of Professors H. Øye and G. Mamantov and Dr. M. Saboungi. Professor N. Watanabe and Dr. T. Nakajima, both of Kyoto University, discussed the anode effect and the key role of graphite intercalation compounds in this effect which is important in both the aluminum and the fluorine production. Another paper on the anode effect was presented by Professor N. Qiu, Northeast Institute of Technology, the People's Republic of China (PRC). There were several representatives from the PRC who, besides being involved in the usual conference activities, distributed a very colorful brochure on the General Research Institute of Nonferrous Metals in Beijing.

Various aspects of the electrodeposition of other metals were also discussed at the symposium such as the importance of nucleation processes in electrodeposition (Professor G. Hills, University of Strathclyde, Scotland), electrochemistry of niobium and electroplating of chromium from molten fluorides (Dr. T. Yoko of Mie University and Professor R. Bailey of Rensselaer Polytechnic Institute), voltammetry of iron in molten chlorides (Dr. G. Inman, Imperial College, England), and electrorefining of ferromanganese (Professor R. Winand, University of Brussels, Belgium).

The importance of molten salts in advanced batteries and fuel cells was evident from the papers of Professor H. Laitinen, University of Florida; Professor G. Janz, Rensselaer Polytechnic Institute; Dr. G. Dunks of Rockwell International, and former coworkers of the author of this review, Dr. M. Matsunaga, Kyushu Institute of Technology, and Dr. A. Katagiri, Kyoto University. A large number of papers dealt with several other aspects of electrochemistry in molten salts; for example, Dr. Y. Ito of Kyoto University discussed the energy analysis of a molten salt electochemical reactor and the anodic behavior of oxide ions in molten fluorides; Professor M. Chemla, University of Paris, talked on the electrochemical behavior of carbon materials in molten flouride systems; Dr. H. Hayashi, Kyoto University, discussed the oxygen electrode reaction in molten NaOH, and Dr. G. Picard, University of Paris, summarized recent work on the electrochemical studies of molten $NaNO_3$-$NaNO_2$ mixtures.

Two sessions were devoted to various aspects of molten salt nuclear reactors; for example, Professor K. Furukawa and a coworker of the Japan Atomic Energy Research Institute presented three papers on molten salt breeder systems, and Dr. H. MacPherson, Oak Ridge Institute of Energy Analysis, discussed the radiation stability of molten fluoride fuels.

Thermodynamic aspects and properties, such as viscosity, electrical conductivity, surface tension, thermal conductivity and hypersonic velocity of several melt systems were discussed in a number of papers. Another topic of interest was isotope enrichment by electromigration in molten salts (Professor A. Klemm, Max Planck Institute, Mainz, West Germany and Dr. I. Okada, Tokyo Institute of Technology).

Structural characterization of melts was discussed in several papers. The methods employed range from x-ray and neutron diffraction, Raman and infrared emission spectroscopy, nuclear magnetic resonance to molecular dynamics using computer simulation. Authors presenting papers in this broad area included Dr. M. Saboungi, Argonne National Laboratory; Dr. K. Kusabiraki, Toyama University; Dr. H. Ohno, Japan Atomic Energy Research Institute; Drs. T. Yamaguchi, M. Itoh, and Y. Takaji, Tokyo Institute of Technology; and Professor K. Ichikawa and Dr. Nakamura, Hokkaido University.

Studies of chemical reactions in molten salts were described by a number of authors such as Drs. M. Nakayasu and K. Usui, Ube Industries; Dr. M. Shinmei, Hokkaido University; Dr. C. Ogiso, Yokohama National University; Dr. K. Tanno, Iwate University, and Dr. Y. Kaneko, Yamanashi University. Finally, the topic of thermal energy storage using molten salts was discussed by several authors including Professor Y. Marcus of Hebrew University, Israel, and Dr. A. Nagelberg, Sandia National Laboratories.

The wide range of topics presented at this symposium is a clear indication of a continuing significant interest in molten salts both from the fundamental and the applied standpoint. The second international symposium in this general area will take place in Paris in the summer of 1986. Professor M. Chemla will chair the organizing committee for that symposium.

UNIVERSITY VISITS

Following the symposium, I visited Professor Akimasa Tasaka, Department of Applied Chemistry, Doshisha University, Kyoto, to learn about Raman spectroelectrochemical studies being conducted in Dr. Tasaka's laboratory. The rest of the day was spent at Kyoto University, initially visiting the laboratories of Professor Nobuatsu Wanatabe (the chairman of the symposium Organizing Committee) who is well-known for his extensive studies on graphite fluorides and related intercalation compounds. The afternoon was devoted to a minisymposium consisting of lectures presented by Professor B. Welch of New Zealand, Professor P. Mergault of France, and by myself. The lectures were well attended by both industrial and academic scientists. I also visited the laboratory of Dr. Hidetaka Hayashi who, working with Dr. Yasuhiko Ito and Professor S. Yoshizawa, (a well-known applied electrochemist who has recently retired) has performed electrochemical studies in molten NaOH.

In general, I was quite impressed with the research programs at Kyoto University. I was somewhat familiar with the work in Professor Yoshizawa's laboratory before my visit to Japan since three of his former students, Drs. Matsunaga, Ogata, and Katagiri, had spent one to two years each in my laboratory working on various aspects of the Na/S(IV) chloroaluminate cell. Only Dr. Katagiri, currently an associate professor in the College of Liberal Arts, has remained at Kyoto University. I was informed that Kyoto University has a half-dozen or so specialized chemistry departments such as polymer chemistry and applied chemistry, and that it has the largest overall chemistry program in Japan.

One final comment about the molten salt program at the University of Kyoto--the Molten Salt Committee of the Electrochemical Society of Japan, currently chaired by Professor Watanabe, publishes a bulletin (in Japanese) which contains scientific papers, news items, and advertisements. The bulletin is in its twenty-sixth year; several issues, each containing approximately 100 pages, were published in 1982. Such a molten salt bulletin may be the only one of its kind in the world.

KYUSHU INSTITUTE OF TECHNOLOGY

After leaving Kyoto, I visited the Department of Industrial Chemistry, Kyushu Institute of Technology, and presented another seminar on molten salt electrochemistry. The person in charge of this department is Professor K. Hosokawa; the associate professor is Dr. Morio Matsunaga, a former coworker of mine. Dr. Matsunaga is a very energetic and a capable person; he has been able to establish, in just a few years, a vigorous research effort in the area of advanced batteries. He has the full support of Professor Hosokawa. Although there is no doctoral program in the Department of Industrial Chemistry at Kyushu, Professor Hosokawa hopes to establish one in the next few years. As is common at other universities in Japan, the students working on their master's degrees devote two years to research without being involved in other duties; in addition, the usually work full-time on research during part of their senior year before beginning their graduate work. It appears that the Japanese graduate students devote much more time to research than American graduate students during their first two years in graduate school. It is not uncommon for a Japanese student to spend 12 hours a day, six days a week in the laboratory; this would be highly unusual in an American university.

The laboratories at Kyushu are well-equipped for electrochemistry; Professor Hosokawa has also established a collaborative effort with another department in the area of photoacoustic spectroscopy of electrode surfaces. The author of this report and Dr.

Matsunaga and Professor Hosokawa have recently submitted a joint proposal to the Division of International Programs, National Science Foundation, and the Japan Society for the Promotion of Science on chemical and electrochemical studies on molten salt batteries. The visit to Kyushu proved useful in establishing a good foundation for a successful cooperative program should the above proposal be funded.

NAGOYA INSTITUTE OF TECHNOLOGY

I next visited Professor F. Hine at the Nagoya Institute of Technology. Professor Hine is a well-known electrochemical engineer who has recently written a book on this subject. Dr. Hine is the head of the Industrial Chemistry Department and is a very prolific researcher; he consults widely in Japan and in this country for the chloralkali industry. His research group currently has 19 coworkers including Dr. Y. Ogata who is a "joshu" (a permanent research associate and instructor); Dr. Ogata spent two years in my laboratory.

I had a very interesting discussion with Professor Hine regarding the organization and teaching in his department. The department has 50 graduate students and 440 undergraduates. The latter spend the first two years on another campus. Electrochemistry and electrochemical engineering are taught in the third year. The department has 11 research groups. The undergraduates attend classes five and one-half days per week; they complete course work by the second semester of their senior year which is devoted mostly to research. An undergraduate thesis is required.

Two years are required for an M.S., and another three years for a doctoral degree. Students usually remain at the same school for graduate work. Contrary to the current situation in the U.S., professors in chemistry have no difficulty in getting an adequate number of well-prepared graduate students who do not get a stipend while performing their graduate research. I found it interesting that my seminar at Nagoya was scheduled for 2:00 P.M. on Saturday afternoon. It was well-attended; the audience included several people from industry and other universities. Dr. Hine's coworkers resumed research activities after my seminar and the discussion. It appears that two of the ingredients of Japanese technological prowess is simply hard work and good professional preparation.

TOKYO INSTITUTE OF TECHNOLOGY

The last institution that I visited was the Tokyo Institute of Technology (TIT). According to my host there, Professor K. Kawamura, the Research Laboratory for Nuclear Reactors in the Department of Nuclear Engineering, TIT has approximately 6000 students including about 2000 graduate students. It is the second oldest institution of higher education in Japan. Professor Kawamura has ten coworkers; five of these work in the area of molten salts. Dr. Kawamura's interests include amorphous metals, thermodynamics, measurements of properties such as ultrasonic velocity, refractive index, density, conductance, and heat capacity, Raman spectroscopy, radiation damage, tritium permeation, and nuclear waste. I was informed that Japan expects to construct, by 1990, a large (2000 tons per year) plant for nuclear waste reprocessing; currently spent nuclear fuel is sent to England or France for reprocessing.

In addition to Professor Kawamura's research group, TIT has other groups interested in molten salts. However, I was unable to visit their laboratories since they are located on another campus at Nagatsuta (near Yokohama). I was able to visit all of Professor Kawamura's laboratories which contain a great deal of very expensive equipment which was obtained through the fushion reactor program. My impression of the programs at TIT

is a very favorable one; TIT is clearly a first-rate institution which likes to be compared with the Massachusetts Institute of Technology (MIT).

INDUSTRIAL VISIT

Besides the four institutions of higher learning, I was invited to visit the Yuasa Battery Company located between Kyoto and Osaka. As part of an 11-year national project started in November 1980 to develop new electric energy storage systems [sponsored by the Japanese Ministry of International Trade and Industry (MITI)], a sodium/sulfur battery is being developed at Yuasa. The battery consists of a series of cells that use ß"-alumina as a solid electrolyte and molten sodium and a polysulfide melt as active materials. My half-day visit to Yuasa was conducted in the same manner as described recently by Dr. Derek Lile [*Scientific Bulletin 8* (1), (48 (1983)]. In a nutshell, it was like a program review for the benefit of a sponsor. After the discussion and my presentation on our battery-related activities, I was given a very interesting tour of the Yuasa facilities that involve the development of the Na/S battery. I was also shown an electric car built in 1977 which was powered by a 30 kW h Na/S battery. Yuasa's current goal is to build a 1 kW/8 kW h battery by the end of 1983. If successful, the system will be scaled up to 10 kW/80 kW h by the end of 1986 and up to 1 MW/8 MW h in 1987. The demonstration of the final unit is scheduled before March 1991. One of the several impressive aspects of Japan's electric energy storage program is the long-range commitment. In the U.S., the commitments appear to last only through the administration currently in power; the technical goals frequently shift drastically when a new administration takes over.

Similar Na/S battery efforts exist in this country as well as in England and West Germany. It remains to be seen which, if any, of these efforts will eventually lead to a commercially viable product.

CONCLUSION

In summary, my visit to Japan has been a very rewarding one. It is hoped it will result in improved scientific contacts and collaboration between our group and several research groups in Japan. I am very grateful to the Office of Naval Research, Far East for providing partial support for this visit.

MOLTEN SALT STUDIES AT THE TOKYO INSTITUTE OF TECHNOLOGY

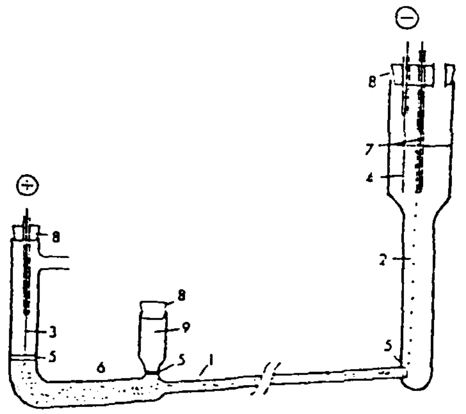
Sachio Yamamoto

One of the papers which was well received at the First International Symposium on Molten Salt Chemistry and Technology (see previous article) was presented by Dr. Isao Okada of the Tokyo Institute of Technology. In that paper he reported that 90% enrichment of ^{6}Li isotope was achieved by countercurrent electromigration. Dr. Okada is an associate professor in the laboratory of Professor Hitoshi Ohtaki in the Department of Electronic Chemistry at the Tokyo Institute of Technology.

Isotope separation by countercurrent electromigration was conceived of by Alfred Klemm in Germany during World War II. Klemm did his work in molten salt media and his first publication on the subject was in 1944. The countercurrent is generated by gravity and capillary forces. As Li^+ ions electromigrate toward the cathode against the countercurrent, ^{6}Li is enriched because of its greater mobility.

Okada started working in this field more than 10 years ago. In 1972, he published a paper reporting the enrichment of ^{7}Li isotope up to 99.9% by this method. It is more difficult to enrich ^{6}Li than ^{7}Li. Gases must be introduced to regenerate the anionic species. In the case of $LiNO_3$, NO_2 and O_2 must be added and with LiCl, Cl_2 is needed. He alleviated this difficulty by using NH_4NO_3 in the cathode compartment and $LiNO_3$ in the anode compartment at 180°C and 300°C respectively. The mobility of NH_4^+ is always greater than that of Li^+-- this is the Chemla Effect, which was so named by Okada. Ammonium ions which diffuse into $LiNO_3$ are thermally decomposed. Therefore, the $LiNO_3$-NH_4NO_3 boundary where the ^{6}Li accumulates can be kept sharp. He succeeded in getting 90% enrichment of ^{6}Li with his cell (Figure 1), 99% enrichment can be achieved with a longer separation tube. Okada is also collaborating with Professor Kazuhata Kawamura of the institute.

Okada's other areas of interest are molecular dynamics simulation of ionic melts and, more recently, study of the mechanism of ion transport in molten salts. In particular, he is studying internal mobilities in binary nitrate systems such as $(Na\text{-}K)NO_3$, $(K\text{-}Cs)NO_3$, and $(Rb\text{-}T\ell)NO_3$. He qualitatively explains the change in cation mobilities with composition in terms of (1) attraction effect (attraction between a certain and neighboring anion), (2) free space effect (total volume less the volume occupied by ion "cores"), and (3) agitation effect arising from the motion of a small and light ion.



Type III

1. molten $LiNO_3$
2. molten NH_4NO_3
3. Pt anode
4. Pt cathode
5. quartz filter
7. thermocouple
8. silicone stopper

Figure 1. Electromigration cell for Li isotope separation.

THE NATIONAL INSTITUTE OF INDUSTRIAL HEALTH

P. F. Iampietro

INTRODUCTION

Rapid industrialization of Japan during the years after World War II provided the opportunity for large numbers of people, workers, and the general population to become exposed to a great variety of chemical and physical hazards created by factories and plants. An increased awareness and activity in the industrial health area led to the enactment of the Labor Standards Law in 1947. The Ministry of Labor established a new National Institute of Industrial Health under its aegis in 1956 in order to provide a facility to do research on these industrial-related problems. In 1972, a new facility was constructed and in 1976 the Ministry of Labor Organization Act was amended to provide for investigation, diagnosis, and the study of the prevention of occupational diseases to be conducted at the institute.

The Institute of Industrial Health is located on a hill overlooking the Tama River in Kawasaki. The facility is attractive and spacious and appears to be well-designed for the kinds of research required under the act. However, a large number of rooms are vacant and unequipped since the number of researchers currently in place is considerably less than the facility can accommodate. There is a facility to house visiting staff. Details concerning the numbers which can be accommodated or the amenities available were not supplied.

The institute is under the guidance of the director, Dr. Hiroyuki Sakabe. In addition to the support sections there are six research departments:

- industrial physiology
- occupational diseases
- experimental toxicology
- industrial epidemiology
- environmental hygiene, and
- human environmental engineering.

During this visit, my interests were focused on the industrial physiology, environmental hygiene, experimental toxicology and human environmental engineering departments. Appendix I shows the activities of each department. Appendix II lists the department heads and senior research fellows in each department. A bulletin of the institute's activities, *Industrial Health,* is published quarterly in English.

- Departmental Visits

The Department of Industrial Physiology appears to be a very productive one. The effects of the work environment, including workload, position, mental stress, shiftwork work-rest cycles and other factors such as isolation, restraint, body physical characteristics and training on catecholamine excretion have been extensively studied. Some interesting results of the relationships of adrenaline and noradrenaline in the various conditions have been described. This research has considerable utility for delineating the relative stresses imposed on man (and animals) under various work and environmental conditions. Dr. A. Sudo, senior research fellow, is the principal scientist in this work. She has published quite extensively over the past several years.

Physiological problems associated with video tape displays (eye, neck, and shoulder strain, visual function impairment, etc.) are being studied by Dr. S. Yamamoto, Chief of the Department of Industrial Physiology, and Dr. Sato, senior research fellow.

Dr. H. Arito, senior research fellow, Department of Environmental Hygiene, has published some very interesting studies of the effects of mercury on biological systems. Mercury has been implicated in Minamata's Disease in Japan. Individuals living in the vicinity of Minamata Bay who ingested methylmercury-contaminated fish exhibited symptoms of insomnia, depression, motor incoordination, posture abnormalities and other signs of poisoning. He has exposed rats to methylmercury and studied the sleep-wake disorders as well as the staggering gait. He postulates that methylmercury inhibits cholinergic neurons thereby causing the sleep disorders. Several research fellows are also active in this department and are working on thermal and metabolic problems.

The Department of Experimental Toxicology is doing work on life span studies in rats as a function of exposure to various levels of ozone. Tissue pathologies are done. Other hazards being looked at are asbestos, methylbromide (used as a fungicide for grain) inhalation studies, and potassium chromate. Dr. H. Kyono, senior research fellow, is primarily responsible for this work.

The Department of Human Environmental Engineering is primarily concerned with vibration studies and has a number of shaking devices for simulation of the types of vibration which might be encountered in industrial situations. Dr. Y. Yonekawa is the principal scientist involved.

For further information inquiries may be addressed to:

National Institute of Industrial Health
21-1, Nagao 6-chome
Tama-ku, Kawasaki, Japan 213

Tel: 044-865-6111

APPENDIX I

DEPARTMENT	ACTIVITIES
Industrial Physiology	- Health evaluation techniques of workers in working environments - Health effects of workers in working environments - Adaptive mechanisms
Occupational Diseases	- Pathogenesis of occupational diseases - Standardization of diagnosis of occupational diseases - Threshold limit values of harmful substances
Experimental Toxicology	- Predictive techniques of toxic effects on workers of potentially toxic substances - Toxicology of potentially toxic substances
Industrial Epidemiology	- Epidemiological studies of health of workers - Epidemiological studies of occupational diseases
Environmental Hygiene	- Measurement techniques of harmful chemical substances - Measurement techniques of hazardous physical factors - Evaluation of hazardousness of industrial environments
Human Environmental Engineering	- Technological improvement of engineering industrial environments - Improvement of man-machine systems - Evaluation of optimum environmental conditions - Personal protective devices

APPENDIX II

DEPARTMENT	PERSONNEL
Industrial Physiology	Chief, Dr. Sohei Yamamoto
	Dr. Kazuko Mori
	Dr. Mitsuo Sato
	Dr. Ayako Sudo
	Dr. Toshio Kakizaki
Occupational Diseases	Chief, Dr. Kimiko Koshi
	Dr. Yasutomo Suzuki
	Dr. Hiroshi Tsuruta
	Dr. Masayasu Minami
	Dr. Takeshi Honma
Experimental Toxicology	Chief, Dr. Hiromichi Hasegawa
	Dr. Masami Kimura
	Dr. Hiroko Kyono
	Dr. Kuniomi Nakamura
Environmental Hygiene	Chief, Dr. Reisuke Soda
	Dr. Akira Hamada
	Dr. Noburu Hara
	Dr. Katsunori Homma
	Dr. Yoshimi Matsumura
	Dr. Heihachiro Arito
Human Environmental Engineering	Chief, Dr. Toshisuke Miwa
	Dr. Minoru Hashizume
	Dr. Yoshiharu Yonekawa
	Dr. Hisao Yotsumoto
	Dr. Takeshi Iwasaki

METAL POWDER PROCESSING IN JAPAN

Michael J. Koczak

INTRODUCTION

The powder research activities in Japan can be considered in two generic areas of metal and ceramic powders. In each of these areas, government-sponsored research activities are being conducted at universities, industrial and national laboratories. As a generalization, the most advanced efforts are typically conducted at industrial research laboratories; in many cases subsidized by governmental research grants, contracts, or components of a larger national research program.

There are two Japanese government bodies, apart from the Ministry of Education, which support materials research, i.e., the Ministry of International Trade and Industry (MITI) and the Japan Research and Development Corporation (JRDC). The MITI program in powder metallurgy, composite materials, and special structure alloys is part of the program entitled "Research and Development of Basic Technologies for Future Industries." Appendix I provides the titles of the papers at the first symposium on metals and composite materials technology sponsored by this program. These efforts pool the talents of industrial engineers, government researchers, and academics into a research area over a long term, e.g., five to ten years. The companies provide the engineers to the program and in return receive a preferred position in developing and marketing the technology and products which are the fruits of these coordinated efforts. The programs involve three areas:

- new materials, i.e., fine ceramics, advanced alloys, and composite materials, membrane separation technology, synthetic metals, and high performance polymers,
- biotechnology, i.e., cell production and recombinant DNA, and
- electronic devices, i.e., integrated circuits and superiattice devices.

The organization and direction of government research programs is oriented to the national, commercial, and scientific background of the country vis à vis its competitive position with other countries. As a result, with a small defense research budget combined with few natural resources Japan must look to future industries to sustain its economic well-being. In addition, it must maintain a competitive edge with regard to newly industrialized countries, i.e., Korea, Taiwan, Brazil in basic industries, e.g., steel, automobiles, electronics. It may be compared to the position of a sprinter trying to overtake a technological gap; at the same time, he is looking over his shoulder upon hearing the footsteps of newly industrialized countries in the areas of shipbuilding, steel, construction, fishing, and transportation. Japan currently exports technology in three major areas: steelmaking, textiles, and construction. These areas are being quickly assimilated and Japan is challenged by the newly industrialized countries which would like to duplicate the economic success of Japan on their own soil. With the aid of low interest loans, high technology information transfer, and low labor costs countries like Korea, Singapore, Taiwan, and Malaysia shall become dominant economic powers.

The selection of research areas for future industries and funding is analagous to steering a fragile glass ship in a stormy sea to a safe harbor. A favorable wind and calm domestic seas, i.e, government funding with no domestic legal or competitive problems is required. Close cooperation between the various industries, academic and government research laboratories is required in order to achieve a safe harbor or a program goal. The

Japanese nation has been compared to a glass boat with many passengers. If the relationship between the captain, crew, and passengers, i.e., government, industry, and labor becomes stormy, the fragile ship of state will fracture and all will be lost. However, if there is a cooperative spirit between the government, company researchers, and labor as well as the general public for the general good of the nation, a prosperous nation can emerge. The above analogy may be an ideal; however, such large-scale directed cooperative research efforts typify the efficient research funding programs in Japan.

In the areas of ceramics, composite materials, powder metallurgy and specially structured alloys such research programs are underway. In comparison to the funding modes in the United States, the research areas are divided into topics and each participant is provided with a segment. Although, the commercial licensing, patent, and marketing aspects are not clearly spelled out, it is imagined that the process development and licensing shall be the territory of the contributing company.

RESEARCH FUNDING IN MATERIALS

Examining the metal and automotive industry, this level of commercial technology in powder metallurgy is dominated by major companies in Japan, i.e., Mitsubishi, Hitachi, Sumitomo Electric, Toyota, Toyo Kogyo. The major companies involved in powder metallurgy on a commercial, i.e., automotive as well as higher technology applications are Mitsubishi Metals, Hitachi, and Sumitomo Electric. They have broad base experience in both areas and possess capable research staffs. Two of these companies are also involved in MITI-sponsored research activities; Mitsubishi Metals Research in titanium and aluminum powder metallurgy, and Sumitomo Electric in the area of mechanical alloying and isostatic compaction of powders. In comparison to their counterparts in the United States, these two companies have an extremely wide ranging capability, i.e., cemented carbides, fully density and low and middle density press and sintered alloys coupled with the technical staff and support equipment to conduct excellent research and development programs.

ORGANIZATION OF POWDER METALLURGY ACTIVITIES

The societies or trade associations which coordinate the metal powder activities in Japan are:

The Japan Society of Powder and Powder Metallurgy
Seisan Kaihatsu Kagaku Laboratory
No. 15, Shimogamo Morimoto-cho
Sakyo-ku, Kyoto, 606 Japan

and

Japan Powder Metallurgy Association
Tamagawa Building 2-16
Iwamoto-cho, 2-chome, Chiyoda-ku
Tokyo, 101 Japan

The Japan Society of Powder and Powder Metallurgy is the more research oriented of the the two associations with semiannual meetings. The meeting is typically divided into two concurrent sessions in the areas of metal and ceramic powders. As a result, one group discusses the area of metal powders as applied to structural application and

structure property relations, while the second group has papers in the areas of ceramics, intermetallics, ferrites, and hard materials.

In the industrial sector, the Japan Powder Metallurgy Association represents over fifty parts, powder, and equipment manufacturers. A summary of the demand of powder parts is provided in Table I and demonstrates a steady growth in shipments of iron powders despite a stagnant world economy. The major producers of iron powder are shown in Table II with their production of reduced or atomized powders:

In the area of nonferrous powders, copper powder shipments have stabilized at 4000 tons per year in 1980 and 1981. In 1982, the monthly shipments of aluminum, brass, and copper powders were 1046, 57, and 479 tons per month showing increases over the previous years' figures. In general, the companies involved in press and sintered component manufacturing do an excellent job with good quality powders and careful process and size control. At the production facilities, visitors are impressed by the introduction and utilization of automatic handling systems, attention to detail and precise control of component size. This ability has evolved by years of experience and numerous minor improvements which have culminated in excellent powder and component processing control.

GOVERNMENT RESEARCH PROGRAMS IN METAL POWDERS

The research programs in metallic powders involve two areas: (1) superfine powders for magnetic, catalyst, solid fuel and structural applications, and (2) powder processing of structural alloys in aluminum, titanium, and nickel base systems. In addition, the research topic on structured alloys, e.g., rapid solidification of strips for transformer and structural alloys, has direct application in the powder metallurgy area.

The organization of the MITI-sponsored powder and composite research project is outlined in Figure 1 showing the interplay between government, industry, and technical societies. The funding is provided by the Research Development Corporation of Japan and the research themes in the materials areas include superfine powders, special structured materials and fine polymers. The superfine powders program led by Chikara Hayashi has twenty researchers examining the production and areas of commercial application of superfine powders. These application areas include utilization of these fine powders e.g., 400 A, for magnetic applications, catalysis, powders for low temperature sintering. The program appears to parallel efforts at ULVAC, and apparently has first option to the technology.

The area of powder metallurgy research on fully density structural alloys is incorporated into a research program entitled "Research and Development Institute of Metals and Composites for Future Industries" (Figure 2). The MITI program was established in August 1981 with a goal to develop the necessary metals and composites for the development of future industries of Japan. The program has two components, (1) high performance crystal controlled alloys, and (2) composite materials. The development of these areas is expected to contribute to the performance and reliability of machine industrv, aerospace, transportation, energy, biotechnology and information processing. The area of research involves three research areas:

- the development of alloys and processing of single crystal turbine blades,

- the development of titanium and nickel base superalloys and superplastic forming of these systems, and

- the mechanical alloying of dispersed oxides, e.g, Y_2O_3 in a nickel-based alloy system.

The major companies involved in this research include Ishikawajima-Harima Heavy Industries, Hitachi, Ltd., Hitachi Metal Industries, Ltd., Daido Steel, Kobe Steel, Mitsubishi Metal Research Institute, and Sumitomo Electric. In support of the industrial research effort, three national research institutes are cooperating, i.e., the Machine Engineering Research Institute, the Nagoya Research Institute of Industrial Technology, and the National Research Institute for Metals.

The program of research involves an eight-year effort, Figure 2, with the final goals involved in the development of the powder processing technology to produce advanced commercial components for industrial applications with the following mechanical property goals:

- Super Heat-resistant Alloys

  1000 hour life at 1040°C at a stress level of 14 kgf/mm^2 and an elongation in excess of 10%

  Tensile strength of 160 kgf/mm^2 at 760°C coupled an elongation of 20% with a materials utilization two times of conventional techniques

- Lightweight, High Strength Alloys

  A specific strength at 300 C° of 28 kgf/mm^2 g/cm^3 coupled with an elongation in excess of 10% with a use efficiency of three times of conventional techniques

The areas of interest in the high performance powder metallurgy areas involve powder production, hot consolidation processing, mechanical alloying, and superplastic forming. The studies concerning powder production involve the National Research Institute for Metals as well as Daido Steel in the respective areas of high pressure atomization and centrifugal atomization. Studies on superplastic forming of titanium are being carried out by Mitsubishi Metal Research Institute. Sumitomo Electric and Ishikawajima-Harima Heavy Industries (IHI) are involved in studies of mechanical alloying. Based upon their previous research history, Hitachi is expected to be involved in single and double roller quenching of structural alloys.

The processing schedules for production of nickel and titanium-based alloys are shown in Figure 3. The studies involving centrifugal atomization have been initiated at Daido Steel utilizing a 35 kg melt with rotational speeds ranging from 5000 to 15,000 rpm with argon, nitrogen, and helium atmospheres. Powders in the 10 to 50 μm range have been produced. Powder atomization via the rotating electrode process at IHI have produced IN100 powders in the size range from 60 to 250 mesh. Electrode rotational speeds ranged from 17,000 rpm to 27,000 rpm with oxygen levels of the order of 14 ppm.

Researchers at Kobe Steel and Sumitomo Electric are examining the area of perform design and hot isostatic pressing (HIP) of powders. The author believes that IHI and Hitachi are involved in roller quenching of structural alloys as part of this program and the results will be contrasted with powder processed alloys. Hitachi clearly has the expertise based on previous efforts and IHI has a single and double roller quenching apparatus and is currently examining MAR M type alloys via the roller quenching

approach. The as-quenched strips of nickel base alloys have strength increases when compared to conventional cast and wrought room temperature strengths. The relative consolidated, high temperature performance is not known; however, the fine grain size permits superplastic forming of these alloy systems.

At this point in time, the diverse research program is concluding its second year. The presentations at the symposium provided an overview; however, extensive details were not provided. The studies on titanium powder processing appears to be most mature while studies on aluminum powder alloys and mechanical alloying are less developed. It shall be interesting to monitor the progress and future developments of this emerging program. In particular, to determine if the performance goals were achieved and/or surpassed. These research and development efforts represent an active, directed effort to improve the processing and develop commercial applications for powder processed alloys.

APPENDIX I

FIRST SYMPOSIUM ON BASIC TECHNOLOGY OF NEXT GENERATION INDUSTRY - METAL AND COMPOSITE MATERIAL TECHNOLOGY

Supported by	Japan Industrial Technology Promotion Association and Next Generation Metals and Composite Materials R&D Assocation
Sponsored by	Ministry of International Trade and Industry (MITI) Industrial and Science Technology Agency

Proceedings

Title	Author
Future material developments	Shimura, A. Director of Materials Engineering MITI Machine Engineering Research Institute

CRYSTAL CONTROL ALLOY SESSION

Outline of superalloy single crystal technology and alloy design	Yamazaki, M. National Research Institute for Metals (NRIM)
Single crystal production technology of superalloys	Nakagawa, S. Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI)
Metal evaluation technology by means of laser speckling	Miakawa, M. Nagaoka Technological University
Superplasticity technology--present and future	Nakazawa, K Ministry of International Trade and Industry (MITI) Mechanical Engineering Laboratory
Powdermaking technology of nickel base superalloys	Kusaka, K Daido Special Metals
Fine powder crystal and plasticity Technology	Takikawa, H. Kobe Steel
Titanium alloy powder and plasticity	Nishino, Y. Mitsubishi Metals Research

COMPOSITE MATERIALS SESSION

Heat resistant resins--development and trends	Tobokuro, K. Toray Industries, Inc.
Shapemaking processing technology for composite materials	Sakaia, Y. Mitsubishi Heavy Industries
Evaluation of reliability and failure of composite materials	Yoshika, H. Ministry of International Trade and Industry (MITI)
Optimal design technology for composite materials structures	Hirano, Y. Tokyo University
Development trends of metal matrix composite materials	Watanabe, O. National Research Institute for Metals (NRIM)

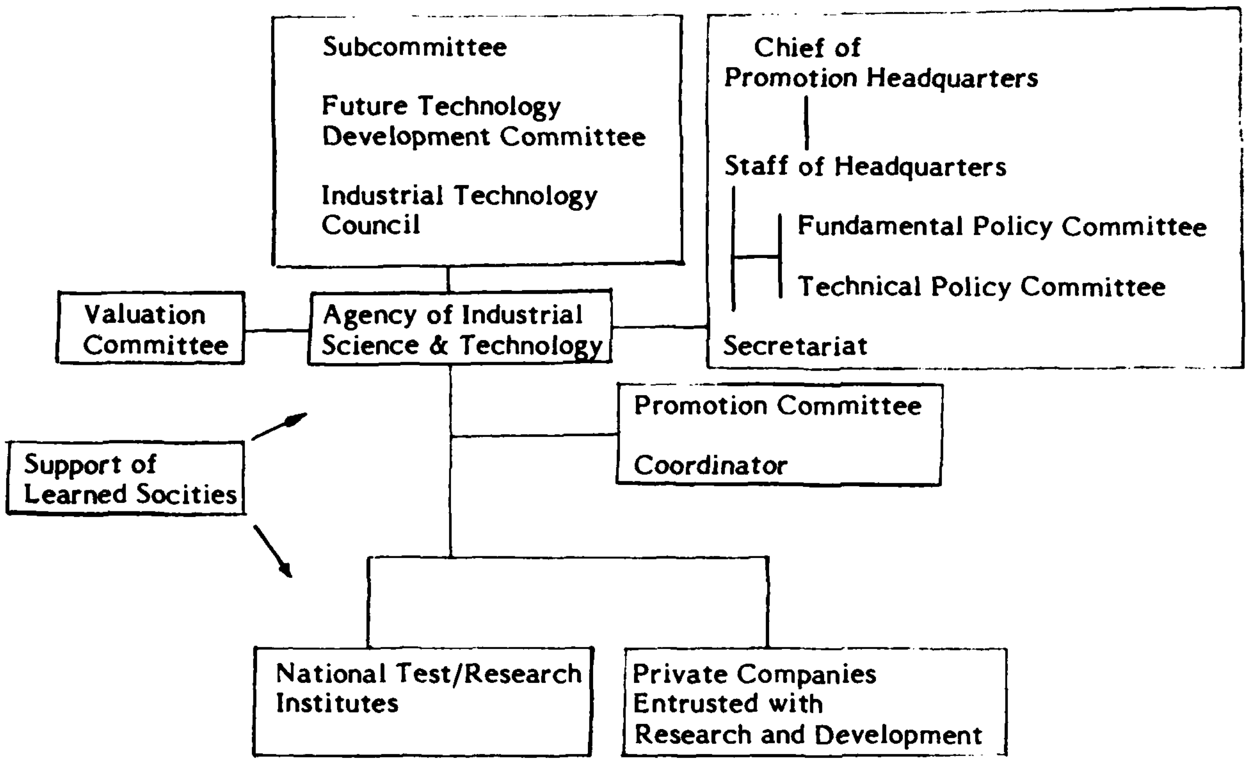


Figure 1. Organization of Research Program

TOPIC	1ST PERIOD (1981, 1982, 1983, 1984)	2ND PERIOD (1985, 1986, 1987, 1988)
(1) Processes for single crystal alloys	Development of production process for melting stock	
	Design/manufacturing of experimental furnace for single crystals	Establishment of casting technique for complicated shapes
	Establishment of basic technique for controlling the growth of single crystals	
(2) Processes for super plastic alloys	Establishment of basic production technique for ultrafine powder	Improvement of performances of production technique, for improving the purity of products
	Development of techniques for small crystalline grain size	
	Establishment of basic techniques for molding work	Establishment of molding technique for complicated shapes
	Development of production techniques for thin film materials	Development of application techniques for thin film materials
(3) Processes for particle-reinforced alloys	Basic investigation on matrix alloys and reinforcing particles	Development of production tèchnique for ultrafine powder
	Establishment of mechanical alloy-producing process and preform technique	
	Establishment of techniques for heat treatment (unidirection recrystallzation), (molding, joining)	
Valuation	Development of general valuation technique	
	Evaluation of the shapes of test piece	Evaluation of complicated shapes

Figure 2. High Performance Materials Program Schedule

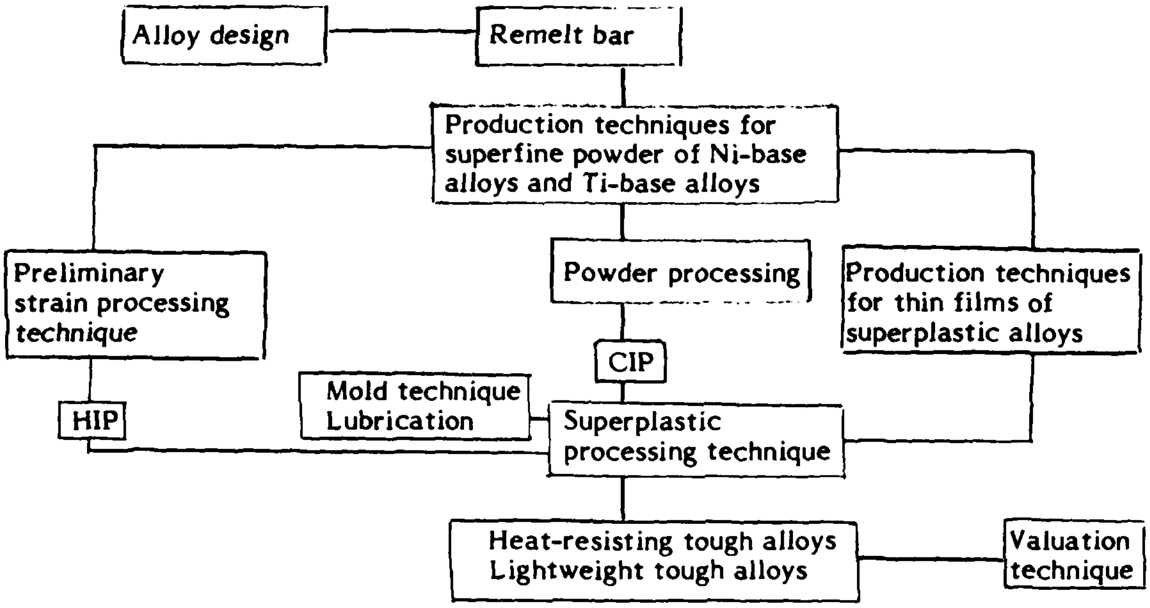


Figure 3. Processing Schedule for Powder and Thin Film Alloys

TABLE I

STATISTICS OF POWDER METALLURGY IN JAPAN(+)

	1980 Tons	1980 Previous Year %	1981 Tons	1981 Previous Year %
Production of Powder Metallurgy Products				
Kind of Products				
Mechanical Materials				
Porous Bearings	6,850	106.3	6,665	97.3
Machine Parts	41,551	124.4	44,401	106.9
Friction Materials	641	96.0	547	85.3
Total	49,042	121.0	51,613	105.2
Electric Contacts	233	102.2	202	86.7
Materials for Bulbs and Tubes	550	107.6	523	95.1
Collector Materials	266	96.7	278	104.5
Magnetic Materials (Hard)	37,038	123.6	36,276	97.9
Magnetic Materials (Soft)	26,395	122.6	25,593	97.0
Others (Excluding Cemented Carbides)	117	103.5	157	134.2
All Total	113,641	122.0	114,642	100.9
Demand for Mechanical Materials				
For Industrial Machinery	5,837	118.8	5,816	99.6
For Electrical Machinery	8,855	126.9	8,253	93.2
For Automotive Industry	32,552	119.7	35,710	109.7
Other Uses	1,798	125.9	1,834	102.0
Shipment of Powders for P/M				
Iron	50,443	114.2	53,496	106.1
Copper	4,007	108.2	4,021	100.3

DISTRIBUTION OF POWDER PARTS
(Base of Tons)

	1980	1981
For Industrial Machinery	11.9%	11.3%
For Electrial Machinery	18.0%	16.0%
For Automative Industry	66.4%	69.2%
Other Uses	3.7%	3.5%
Total	100.0%	100.0%

(+)Courtesy of Japan Powder Metallurgy Association

TABLE II

IRON POWDER PRODUCTION IN JAPAN IN 1982

	Total (Tons)	Reduced Powder	Atomized Powder
Kawasaki Steel	33,000	23,000	10,000
Kobe Steel	24,000	-	24,000
Dowa Iron Powder	31,000	31,000	
Nippon Iron Powder	15,000	12,000	3,000
TOTAL	103,000	66,000	37,000

METALLURGY IN THE PEOPLE'S REPUBLIC OF CHINA

Michael J. Koczak

INTRODUCTION

A view of the People's Republic of China must be considered in terms of its political history, people, natural resources and its relationships with foreign nations, notably the United States, Japan, and the U.S.S.R. In addition, important consideration must also be given to population and the growth of the population in the next 50 years and this major influence upon the demands and composition of China's economy.

As a result, the population projections, available natural resources, agricultural, electric power and manufacturing capacity are quite dominant factors which are clearly felt by the industrial establishment, scientists, and scholars. In order to raise living standards, research and development is directed to utilize mineral wealth, develop new technologies and increase production capacity and efficiency. Consequently, clear and direct interplay exists between the government's directives, industrial and academic research. Domestic needs, military requirements, and export considerations exert influences on university professors and industrial engineers in terms of research and development directions.

In order to gain a perspective, an introduction shall be provided which documents population, physical size, projections of population and economic growth. This will assist in demonstrating the strengths and weaknesses of China. Assets are in abundance, e.g., mineral and agricultural products as well as a large, low cost labor force. This must be balanced by the projection of a 50% population increase in 50 years, the remnants of previous political upheavals and a largely agricultural work force. With regard to natural resources and manufacturing output, the relative level of the current Chinese economy in six major areas coupled with the manufacturing output are examined. In the materials area, specific attention shall be directed to the ferrous industry and export/import commodities in ferrous and nonferrous metals, polymers, synthetic and natural fibers. The balance of the article will contribute to an understanding of the education and metallurgical research activities within the constraints of political changes, a large population, governmental directives, and natural resources.

The development of research in metallurgy, according to Professor T. Ko of the Beijing University of Iron and Steel Technology, can be considered in three phases. During the initial stage of development from 1952 to 1960, the establishment of research laboratories was initiated. These research establishments can be divided into five groups:

- university research facilities,
- research institutes supported by Academia Sinica,
- research institutions maintained by ministries, i.e., Ministry of Metallurgical Industries,
- research institutions supported by regional authority, i.e., Shanghai, Beijing, etc., and
- research facilities supported by industries.

The second phase of development, from 1960 to 1966/1976, concerned utilization of abundant resources, e.g., Fe, Cu ore development; Ni, Nb, V, Ti extraction; elimination of Cr, Co and Ni in low grade, high production steel products, i.e., low Cr bearing steels;

also, development of the semiconductor industry and optimization of energy utilization. From 1977, the third phase involved improvement of quality control, reduction of energy consumption in metallurgical industries. Fundamental studies were urged, e.g., fracture mechanics, hydrogen embrittlement, stress corrosion cracking, amorphous materials as well as development of new technologies, e.g., precision cold rolling, new heat treatment techniques.

It is intended for the article to provide a profile of the industrial and material resources of the People's Republic of China, examine the metallurgy industry, education, and research in specific laboratories and universities, and to comment on the growth potential of science and technology in China. In compiling the information, the data are obtained from United Nations reports, Chinese publications as well as periodicals, and represents a distillation of information coupled with discussions with Chinese educators and industrial engineers. Although the report is limited, it is hoped that it will present a correct view of the People's Republic of China which shall stimulate further interest and exchange.

RESOURCES

An understanding of the People's Republic of China can be gained by an examination of statistics concerning the people, the country, natural resources, industrial capacity, and economy. The current population of China is over one billion. On a world basis, the Asian subcontinent, to include, China, India, the Philippines and Indonesia, accounts for 44% of the total world population (Table I). Projections indicate (Table II) the increases in populations of China, India, the Philippines and Indonesia shall be 52%, 80%, 121% and 69% respectively over the next 50 years. The growth rate of economic goods and services for the Asian subcontinent currently is one of the highest and is estimated to continue at the current high level for the next fifteen years (Table III). The Asian subcontinent, therefore, represents an important market, industrial and economic force with a projected sustained yearly growth of 7% *vs.* 2% for industrialized countries.

With regard to natural resources and the relative distribution *vs.* countries of North America, Latin America, Europe, Africa, the Soviet Union and Asia/Australia, the Asian/Australian countries appear to have a good balance of petroleum, coal, iron ore, uranium and forest products (Table IV) when compared to Africa and Latin America who lack energy resources. The energy reserves, i.e., coal and oil, are the largest of any area with respectable uranium and iron ore deposits. These factors, coupled with a stable political climate, inexpensive raw materials, an inexpensive labor force can provide China, as well as other countries in this area, a potential for major economic as well as technological growth. It is projected by the year 2000, China shall have an output of $660.0 billion and rank as the seventh largest economic power (Table V).

The gross output of major industrial and agricultural products such as coal, petroleum, steel, electricity, grain, and cotton are listed in Table VII. It is informative to examine the relative placement of China *vs.* the more industrially developed countries, (Table VII). The People's Republic of China is the fifth largest in steel production, third in terms of coal, sixth with regard to electricity and crude petroleum output and second with respect to cotton and grain production. In terms of oil, natural mineral resources, e.g., coal, iron and rare-earth minerals, resources have been estimated at 200 x 10^9, 44 x 10^9 and 36 x 10^6 tons, respectively. China also possesses the largest world reserves of tungsten, antimony, and tin with abundant supplies of zinc, lead, copper, aluminum, nickel, molybdenum, manganese, tantalum, niobium, mercury, and

titanium. A comparison of the major materials exported and imported from China is provided in Tables VIII and IX respectively. Import of finished steel and nonferrous products as well as synthetics and polymers is required. In comparison, export strength lies in coal, oil, glass, paper, and cotton products.

The manufacturing output of China relies heavily on the ferrous industry; it produces approximately 35 million tons of steel annually of which 26 million tons is in rolled steel, e.g., plates, rods, and sheets. In 1981, it imported nearly the same amount of steel. In addition, it imports nonferrous alloys, i.e., aluminum, copper, and zinc (Table VI). Although reserves are available in nonferrous material, it appears that the previous emphasis on the ferrous industry is being readjusted and the mining, extraction of nonferrous materials is receiving needed attention. The balance of ferrous manufactured products is shown in Table VI. The industrial output of China has growth dramatically with regard to new materials and manufactured goods since 1949. It is interesting to note that during the cultural revolution, the period from 1966 to 1976, a drop in production occurred. In terms of steel products, since 1971, production of pig iron has grown by 50% and rolled steel products have doubled and plate glass production has nearly tripled. The production of ethylene, plastics, and tires has multiplied by 15 times, 4 times and 2 times respectively since 1971. In terms of energy utilization, the heavy reliance on coal still persists; however, greater utilization of petroleum, natural gas, and hydroelectric power has been demonstrated such that 70% of energy is supplied by coal *vs.* 95% in 1960.

Despite the growth of industries and the eagerness and willingness of the Chinese people to accept modernization, many constraints limit growth in production capacity namely, limited electric energy output, the large geographic scale of the country coupled with transportation and logistic considerations.

VISITS TO EDUCATIONAL INSTITUTIONS AND RESEARCH LABORATORIES

- Metallurgy Education In China

The educational institutes in the People's Republic of China totaled 704 in 1981, with 207 graduating students in engineering and science. In 1981, the engineering and science universities had a full-time academic staff of 101,776 and a total staff of 286,063. The total number of students in materials/metallurgy is approximately 15,000 with a teaching staff of 3000. Annually 3500 students graduate with a metallurgical degree. Major universities include the Beijing University of Iron and Steel Technology, the Northeast Institute of Technology, and the Central South Institute of Mining and Metallurgy. The major areas of study involve metal physics, physical metallurgy, iron and steel process metallurgy, metal forming, welding, and foundry engineering. Upon completion of the degree requirements, the research-oriented students pursue advanced degrees or find employment at research institutes while other students go on to primary and manufacturing production plants.

- The Beijing General Research Institute For Nonferrous Metals

The Beijing Central Research Institute for Nonferrous Materials was established in 1952 with the support of the Ministry of Metallurgical Industries. The research programs are divided into the areas of ore dressing, extractive metallurgy, physical metallurgy and processing of nonferrous materials, semiconductor materials, physical and chemical analysis, information services and technical economic research. The staff of the institute is comprised of 80 senior staff engineers, e.g., professors or associate

professors, and a support staff of 1000. The functions of the institute includes research as well as training. Appendix I provides a listing of the research topics for each of the subgroups. Emphasis is devoted to ore processing and manufacturing technology. The ore dressing, physical metallurgy and processing groups are involved with the manufacturing cycle of iron extraction, beneficiation and fabrication of finished shapes. Institute support and "guidance" is from the Ministry of Metallurgical Industries. However, it was difficult to assess the interplay of the industry and the institute. Namely, the extent of joint research between industry and the institute as well as the extent of sponsorship of research programs.

Areas of alloy development include the titanium system; (i.e., Ti-6Al-4V, Ti-7Al-4Mo alloys for medical implants as well as structural alloys) cast and wrought aluminum alloys research involves Al-Li-Cu, Al-Cd, Al-Li-Mn, Al-Cu-Sn-Pb-Si, and Al-Pb-Sn systems. Research in aluminum powder metallurgy produced by nitrogen atomization is involved with Al-Pb-Sn alloys for bearing applications. Studies are also being conducted on Zr-Al and V-Al alloys systems. At the Beijing Institute for Powder Metallurgy Research, the Central Iron and Steel Research Institute (CISRI) has a Leybold-Heraus (65 kg) atomization facility for ferrous and superalloy powder production; further details concerning activities at CISRI are provided in Dr. Freeman's article in the *Scientific Bulletin 8* (3), 26, (1983) and in a earlier issue by George Sandoz [*Scientific Bulletin 6* (4), 14, (1981)].

- Beijing University of Iron and Steel Technology

The Beijing University of Iron and Steel Technology is supported by the Ministry of Metallurgical Industries and specializes in ferrous technology with departments in the following areas: mining, metallurgical engineering, physics and chemistry, automation, mechanical engineering and materials science and engineering. With a student to faculty (staff) ratio of 4:1, it has a student body of 4000 undergraduates and 300 graduate students. The university operates as a self-sustaining entity with housing, health services and subsidized meals being provided with tuition assistance. The major emphasis is upon undergraduate training with a small initial effort toward graduate research. The Faculty of Materials, headed by Professor Zhang Shouha, is involved in research areas of powder metallurgy, high temperature alloys, precision metals and alloys, magnetic materials, physical metallurgy and heat treatment. The Materials Department graduates approximately 80 students per year with the students going on to research institutes, nonferrous and ferrous industries as well as machinery industries. The graduate student enrollment in the department is 15 with two to two and one-half years required to complete a M.S. and a similar time period for the M.S. to Ph.D. program. Active research is being conducted by Professor Ho-Yi Lai of the Materials Engineering Department in tungsten-carbide and boron-nitride cutting tool materials.

- Northeast Institute of Technology-Shenyang

The Northeast Institute of Technology, (NEIT) is a technological university composed of 1400 faculty members of 300 professors and associate professors. The student enrollment has 5000 undergraduates and 200 postgraduate students. The structure of the university involves 11 departments and six research institutes. The departments include mining engineering, ferrous metallurgy, nonferrous metallurgy, metallic materials, plastic working of metals, mechanical engineering, automatic control, thermal energy engineering, management engineering, mathematics, physics, and the graduate school. The six research institutes specialize in mining engineering, metallurgical engineering, materials science, mechanical engineering, processing

technology of materials surfaces, and automation. In addition, the NEIT publishes a quarterly journal with English abstracts to promote international scientific exchange. A partial listing of selected titles from the *Journal of Northeast Institute of Technology* is provided in Appendix II as indications of the metallurgy research efforts. Research is currently directed toward aluminum and titanium alloy developments, deformation processing, and extractive metallurgy in ferrous systems.

- Shanghai Iron and Steel Research Institute

The Shanghai Iron and Steel Research Institute (SISRI) is an advanced materials research and development laboratory with associated pilot plant facilities. The departments include: specialty steel, precision alloys, superalloys and titanium, refractory metals, getter alloys, welding, machinery and automation, physical testing, chemical analysis, and information. A separate technology branch has four departments in steelmaking, metalworking, metal plasma spraying and roll forming. The laboratory facilities are well-equipped with quality microscopy, quantitative metallography and chemical analysis instrumentation. The pilot plants have the capacity for VIM, VAR, EBM, ESR and skull melting. The rolling mills include Sendimir rollings, cold bond composite rolling as well as conventional hot and cold rolling facilities. Research is also conducted on plasma spraying, isostatic pressing as well as unidirectional solidification of nickel base alloys. The products produced by SISRI include metal strips, e.g., Fe-Si, seamless stainless steel tubes, permalloy Alnico, Invar, and Kovar alloys as well as W-Re and Mo wires. The visit to SISRI was brief; however, it demonstrated a research and pilot plant capacity to manufacture a wide variety of cast and wrought, powder metallurgy, and composite sheet products with direct commercial application. The SISRI is very well-equipped and staffed. The funding for the research programs is equally balanced between the Chinese Ministry of Metallurgical Industries, the Shanghai Metallurgical Industry Bureau and industrial funding. The impressive facet of this institute is the range of research and commercial products coupled with the wide range of research and pilot plant facilities.

- Central South Institute of Mining and Machinery

The Central South Institute of Mining and Machinery is located in Changsha, Hunan province. The Vice President of the Institute is Professor Huang Pei-yun, an active researcher in powder metallurgy; as a result, the school has a strong undergraduate program in powder metallurgy research. Professor Huang Pei-yun has authored a five-hundred page powder metallurgy text book which reviews the fundamentals of powder atomization, compaction, sintering as well as advanced topics of full density structural alloys and tungsten base materials. The research conducted by the powder metallurgy group appears very active. Professor Fritz Level of Rensselaer Polytechnic Institute (RPI) had lectured for three weeks in Changsha and the institute maintains ties with academics in West Germany, Japan as well as the United States. Also in Hunan province the largest Chinese cemented carbide plant exists in Zhuzhou with an annual production capacity of 1500 tons of cemented carbide products. Research areas at the Central South Institute involve preform forging for agricultural equipment parts, titanium laminates, Cu-Al powder forging and rolling. Studies are being carried out in mixed elemental aluminum powder alloys, i.e., Al-4 w/o Cu-0.6 w/o Mg utilizing liquid phase sintering to achieve densities of 95% of theoretical and strength levels of 28 kg/mm^2. Carbon particulate reinforced aluminum alloys are produced by blending carbon black, stearic acid and aluminum powders. Following hot compaction, strengths of 40 kg/mm^2 combined with ductilities of 10% are obtained. Additional studies of dispersion

alloys, e.g., Fe-Cr-Al-Y as well as tool steel are conducted with the cooperation of Fulmer Research Institute. Based upon the excellent research exchanges and the direction of Professor Huang Pei-yun, the group at Central South Institute in Changsha has an active, well-balanced effort in powder metallurgy.

- The South China Institute of Technology

The South China Institute of Technology located in Guangzhou (Canton), was founded in 1952 with a student body at 8000 students and a staff of 2200, i.e., 250 professors, 200 associate professors with the balance being instructors, lecturers, and assistants. Ninety-five percent of the research funding at the institute is provided by the various ministries, i.e., the Ministry of Education, the Ministry of Metallurgical Industries, etc. An additional 5% percent is obtained from industrial sources. A research group may receive 5,000 to 10,000 yuan (1.90 yuan = $1.00) for a research project with the university receiving 30% in overhead. Student and faculty support is provided separately by the state. Additional financial support can be received from the state in the form of prizes or awards for outstanding achievements. Each year, 20 overseas guests are invited to lecture and participate in joint research programs with Swedish, Japanese, and West German faculty members being the most popular.

The College of Technology has eighteen departments with forty-two specialities, e.g., mechanical engineering, chemical engineering, ship construction, inorganic materials, polymers, electrical engineering, radio, automation, computer science, architecture, civil engineering, mathematics, and physical chemistry. Professor Chan, my host, conducted research on Al-Cu-Li alloys with Professor Grant at MIT, and has current research in aluminum alloys. The production of aluminum-zinc (6 w/0) powder (-40 mesh) via gas atomization and titanium powders via the rotating electrode process and the hydrid-dehydrid process are being accomplished at industrial facilities in the Guangzhou region. There was interest in Ti-Al-V, TiB_2, TiN_3 CrN_3 as well as refractory alloys, i.e., Zr, W, and Mo.

SUMMARY AND IMPRESSIONS

The development of science, higher education and technology is a story of early progress that followed the stagnant period of the cultural revolution (1966-1976). At this time, science was barely flourishing and the educational institutions were being restructured with major personnel changes. The present situation is a slow, but steady return to normalcy in terms of a more stable administrative and political structure. However, remnants of the debilitating cultural revolution remain at the educational and research levels. The current scientists are very eager to assimilate and utilize the most recent developments. Although the academic and research climate is clearly superior, the diffusion of research concepts and manufacturing developments is hindered by the lack of sufficient financial resources, a support staff which is being created as well as a slow, centralized research administrative structure.

Metallurgy research is directed at several levels, e.g.,

- improving production capacity and quality of ferrous products,
- development of extraction capacity for nonferrous and rare-earth metals, and,
- improvement of powder metallurgy processing for titanium and nickel base superalloy materials.

Several research institutes are doing excellent work, i.e., SISRI in manufacturing and pilot plant capability, the Central South Institute of Mining and Metallurgy in powder metallurgy research, and the Central Iron and Steel Research Institute. The number of researchers at institutes and universities is staggering with many being underemployed. Many bright, friendly, and eager scholars are willing to learn the most recent developments and apply that knowledge at the university, research, or industry level. The assimilation of knowledge can occur very rapidly; however, the application step is certainly more difficult. Nevertheless, the Chinese are a patient and persistent people and many individuals have the drive and productivity to further develop science and technology.

APPENDIX I

RESEARCH TOPICS AT BEIJING GENERAL RESEARCH INSTITUTE FOR NONFERROUS MATERIALS

- Ore Dressing and Metallurgy

    Techniques and equipment ore dressing of heavy nonferrous and ore metals
    Synthetic organic reagents
    Hydrometallurgy
    Enviromental protection
    Mineral resource development
    Physical chemistry of chlorination
    Electrolysis on nonferrous metals
    Examples of research: recovery of tungsten, precious metal extraction, production of lithium and tantalum, Sm-Co alloy development

- Physical Metallurgy and Processing of Nonferrous Metals

    Fabrication of plates, rods, cylinders via conventional cast and wrought techniques as well as powder processing
    Metal spinning, hydrostatic extrusion
    Welding, vacuum metallurgy
    Structure/property relations
    Corrosion mechanisms
    Flame spraying
    Manufacture of silver-copper composites

- Semiconducting Materials

    Preparation of single and polycrystal silicon
    Preparation of high purity germanium and germanium compounds
    Compound semiconductor manufactures, e.g., GaAs
    Experimental techniques involving Hall effects, x-ray
    Topography, infrared spectroscopy

- Analysis and Physical Testing

    Atomic absorption
    High voltage electron microscopy
    X-ray fluoresence
    Neutron activation analysis
    Quantitative metallography

- Research and Development of Special Equipment

    Production of metal forming and vacuum equipment
    Equipment design

- New Products

    Spin tubes
    Ti-Cu, Cu-Al composite metals
    Germanium, silicon, GaAs, GaP single crystals
    Sm-Co alloys

APPENDIX II

SELECTED TITLES FROM

JOURNAL OF NORTHEAST INSTITUTE OF TECHNOLOGY

Volume *I*, 1981

Title	Name
The Law of Decreasing of Trace-metal Concentration in Aluminum Electrolysis	Qui Zhu-zian
A New method for Measuring the Strain Rate Sensitivity Index of Superplasticity	Wu Qing-ling
Raising and Circulating of Liquid Aluminium in Electrolysis of Aluminium	Di Hong-li
Effects of Rare Earth on Zener' Relaxation and Grain Boundary Relaxation of Ternary Fe-25 Cr-5 Al Alloys	Guo Shi-wen

Volume *II*, 1981

Title	Name
Three-dimensional Orientation Analysis for Cold-rolling Titanium Alloy (TA7) Sheet	Liang Zhi-de *et al.*
Some Problems on Development of High Strength Weldable Al-Zn-Mg Alloys	Lin Zhao-gi *et al.*
Penetration Length of a Side-blown Oxygen Jet by Immerged Lance in Molten Steel Bath	Xu Wen-pai *et al.*

Volume *III*, 1981

Title	Name
The Determination of Crack Initiation in TPB Specimens of Medium-high Strength Steels by Means of Computer	Lai Zu-han *et al.*
On the Corrosion of Mo-MgO Ceramal Casing Tube under Continuous Measurement of the Temperature of Molten Steel	Wang Kui-han, Cui Chuan-meng
On the Kinetics of Reduction of TiO in Blast Furnace Slags by Graphite Carbon	Zhan Qing-lin, Ji Chun-lin
Fe-Si System Alloys: Their Valence Electron Structure, Plasticity Mechanism and Magnetic Properties	Yang Hong-cai *et al.*

Volume *IV*, 1981

The Dispersion of Silica Fine Particles by Acidified Sodium Silicate and Ferric Nitrate	Qiu Ji-cun *et al.*
On the Lateral Force and Optimum Off-centering of the Smaller Roll in Asymmetrical Rolling	Wang Ting-pu *et al.*
New Formu'as for Calculating the Pressure under Forging Reduction	Chen Jia-min
A Theoretical Consideration of Formation Conditions of Granular Bainite in Microalloyed C-Mn Steel	Liu Wei-jie *et al.*

Volume *I*, 1982

Studies on Anode Effect in Aluminium Electrolysis	Qiu Zhu-xian *et al.*
The Features of Structural Discontinuity and Slope Stability in the Dagushan Strip Mine	Lu Shin-hong
The Application of Rare Earth to the Free-cutting Steel--An Investigation of the Steel 20CrRES	Zai Xiang-yong, Liu Yong-quan
An Approach to Graphitization in Cast Iron	Liu Ziang *et al.*
The Determination of Technical Parameters in Laser Transformation Hardening to CrWMn Steels	Liu Chan-gren, Zhu Wei-yong
On the Phase Transformation and the Magnetic Properties of Fe-Ni 25~30% Alloys.	Sun Gui-ru
On the Effect of ß-phase in Ni-Mo Alloy on Its Mechanical Properties	Liu Qing-guo *et al.*
Research on the Reduction Process of Iron Ore Pellets in Rotary Kiln	Fang Jue, Li Yin-tgi

Volume *II*,1982

Some Consideration on the Principles in Managing the Intensity of Labor and Worker Productivity	Kurosawa Kazukiyo
An Experimental Investigation of the Effect of Grinding Wheel Speed on Steel Conditioning	Wang Wan-shan *et al.*

Research on the Inoculation Mechanism of Al in Grey Cast Iron	Hu Huo-sheng
Regression Analysis of the Influence of the Minor Additions Cu and Zr on Weld Cracking Sensitivity in Al-Zn-Mg Alloys	Lin Zhao-gi, Sun Gui-jing
On the Construction of Potential-ph Diagrams of Both the Pb-H_2O and Pb-H_2O-S Systems at Elevated Temperatures	Song Qing-shuang

Volume *III*, 1982

The Deformation Characteristics in Cross Shear Cold Rolling of Ultrathin Strip and the Theory of "Elastic Stopper"	Yu Jiu-ming, Zhu Quan
An Analysis of Plasticity, Strength and Melting Point of Ni-Co System Alloys Based on the Empirical Electron Theory	Zhang Bing, Zuo Xiu-zhong
Kinetics of Reduction Process of Iron Oxides--The Parabolic Formula Derived on the Basis of Thermodynamics of Irreversible Process	Zhai Yu-chun
The Behavior of the Microalloyed Steel 15MnVTi under Static Bending in Connection with Its Structure	Cao Ren-huan, Yan Zhen-gi

Volume *IV*, 1982

On the Iron Melting in Bottom Blasting Cupolas at Lower Blast Velocity	Shi Ting-zao *et al.*
Operational Performance of DC Electromagnetic Pump in a Pig Cast Machine	Gao Yun-yan, Zhang Zhen-huan
An Approximate Evaluation of γ'-Phase Fraction in Age-hardened Fe-Ni-Cr Base Superalloys	Yang Hong-cai
Fracture Analysis of ZG20 MnSi Steel as Caused by Fatigue and Corrosion Fatigue	Cai Qing-kui, Cui Guang-chun
Computer Applications in China: Problems and Opportunities	D. G. Woods

Volume *I*, 1983

A Comparison between the Properties of Si5A Steels with and without Widmanstätten Ferrite	Sun Zhen-yan *et al.*

TABLE I

POPULATION AND AREA OF MAJOR COUNTRIES

COUNTRY	Surface area (10 thousand km^2)(1)	Mid-year population 1980 (Millions of Persons)(2)	Average growth rate per annum 1971-1980(%)	Population density 1980 (persons/km^2)
WORLD TOTAL	13,583.0	4,415.0	2.0	33.0
China	960.0	982.5	1.8	102.0
United States	936.3	227.6	1.0	24.0
Japan	37.2	116.7	1.2	314.0
Federal Republic of Germany	24.8	61.5	0.1	248.0
United Kingdom	24.4	55.9	0.1	229.0
France	54.7	53.7	0.6	98.0
Canada	997.6	23.9	1.2	2.4
Australia	768.7	14.6	1.6	1.9
U.S.S.R.	2,240.2	265.5	0.9	12.0
India	295.2	657.2	2.1	222.0
Indonesia	190.4	148.0	2.2	78.0
Mexico	197.3	71.9	3.6	36.0
Brazil	851.2	123.0	2.9	14.0

Note: (1) The total surface area is 149,500,000 km^2. Inhabited population is 135,830,000 km^2,except the Antarctic continent which is not inhabited.

(2) For data on China's population, refer to end of 1980.

Foreign data sources: Population and surface area from the *Statistical Yearbook of China 1981*. Economic Information and Agency, Hong Kong, (1982).

TABLE II

POPULATION PROJECTION
(in Millions)

	Population Now	2033	Change	
China	1,000.0	1,516.0	Up	52%
India	728.0	1,311.0	Up	80%
Soviet Union	273.0	366.0	Up	34%
Nigeria	85.0	335.0	Up	294%
Brazil	131.0	333.0	Up	154%
U.S.	232.0	306.0	Up	32%
Indonesia	154.0	261.0	Up	69%
Japan	120.0	131.0	Up	9%
Mexico	73.0	171.0	Up	121%
France	54.0	57.0	Up	6%
Italy	58.0	56.0	Down	3%
West Germany	62.0	54.0	Down	13%
Britain	56.0	53.0	Down	5%
Canada	25.0	38.0	Up	52%

Basic data: *U.S. News and World Report*, May 9, 1983.

TABLE III

PERCENTAGES OF RATES OF ECONOMIC GROWTH

	1980-1985	1995-2000
North America	1.96	2.20
Western Europe (North)	1.80	2.00
Western Europe (South)	2.80	3.00
Eastern Europe	3.50	3.50
Japan	3.89	4.00
Middle East	4.80	7.00
North Africa	6.88	7.00
Indian Subcontinent	6.30	7.00
South Korea, Taiwan, Hongkong, Singapore	8.45	7.00

Basic data: *U.S. News and World Report*, May 9, 1983.

TABLE IV

PERCENTAGE OF WORLD SUPPLY OF MATERIALS

	Oil	Grain	Uranium	Coal	Iron Ore	Forests
North America	6	24	42	29	23	14
Latin America	12	4	2	0	11	16
Europe	4	16	2	26	3	4
Asia and Australia	61	32	19	19	12	27
Soviet Union	9	10	n/a	119	42	16

Note: Percentages show proved or recoverable reserves of oil, uranium, coal and iron ore, and estimated 1982-83 production of grain. Uranium figures exclude the Soviet Union. Figures for each resource may not add to 100% because of rounding or portions that cannot be allocated.

Basic data: *U.S. News and World Report*, May 9, 1983.

TABLE V

ESTIMATED WORLD ECONOMY IN THE YEAR 2000

	Estimated Output in 1982 in U.S. Dollars (in Billions)
1. U.S.	$5,298.0
2. U.S.S.R.	$2,657.0
3. Japan	$2,041.0
4. West Germany	$1,175.0
5. France	$1,014.0
6. Britain	$ 875.0
7. China	$ 660.0
8. Brazil	$ 562.0
9. Italy	$ 522.0
10. Canada	$ 461.0

Basic data compiled by *U.S. News and World Report*, May 9, 1983.

TABLE VI

CHINA'S MANUFACTURED OUTPUT 1980-1981(+)

ITEM	Unit	1981
Natural gas	100 million m^3	127.4
Gasoline	10 thousand tons	1,111.9
Diesel fuel	10 thousand tons	1,777.9
Electricity	100 million W h	3,092.7
Of which:		
Hydropower	100 million W h	655.5
Pig iron	10 thousand tons	3,416.6
Steel	10 thousand tons	3,560.4
Rolled steel	10 thousand tons	2,670.1
Of which:		
Heavy rails	10 thousand tons	55.64
Light rails	10 thousand tons	73.04
Ordinary rolled steel, medium	10 thousand tons	261.40
Ordinary rolled steel, small	10 thousand tons	627.64
Quality rolled steel	10 thousand tons	210.39
Wire rod	10 thousand tons	462.92
Thick steel plate	10 thousand tons	1.95
Medium-thick steel plate	10 thousand tons	303.28
Silicon steel sheet	10 thousand tons	24.94
Strip steel	10 thousand tons	62.11
Seamless steel pipe	10 thousand tons	91.90
Machine-made coke	10 thousand tons	3,172.0
Iron ore	10 thousand tons	10,459.0

(+) *Statistical Yearbook of China 1981*. Economic Information and Agency, Hong Kong (1982).

TABLE VII

RANKING OF MAJOR INDUSTRIAL AND AGRICULTURAL PRODUCTS BY COUNTRY

COAL

COUNTRY	Output 1980 (100 million tons)	Precedence in the world
WORLD TOTAL	37.36	
United States	7.58	1
U.S.S.R.	6.53	2
China	6.20	3
German Democratic Republic	2.58	4
Poland	2.30	5
Federal Republic of Gemany	2.17	6

Note: Coal output includes hard coal and lignite.

Foreign data sources: *Statistical Yearbook of China 1981*. Economic Information and Agency, Hong Kong (1982).

CRUDE PETROLEUM

COUNTRY	Output 1983 (10 thousand tons)	Precedence in the world
WORLD TOTAL	297,900	
U.S.S.R.	60,300	1
Saudi Arabia	49,572	2
United States	42,398	3
Iraq	12,986	4
Venezuela	11,440	5
China	10,595	6

STEEL

COUNTRY	Output 1980 (10 thousand tons)	Precedence in the world
WORLD TOTAL	74,900	
U.S.S.R.	14,800	1
Japan	11,141	2
United States	10,080	3
Federal Republic of Germany	4,381	4
China	3,712	5
Italy	2,650	6

ELECTRICITY

COUNTRY	Output 1980 (100 million W h)	Precedence in the world
WORLD TOTAL	80,440.0	
United States	23,561.4	1
U.S.S.R.	12,950.0	2
Japan	5,140.3	3
Federal Republic of Germany	3,687.7	4
Canada	3,663.6	5
China	3,006.0	6

Note: Public power stations and self-owned power plants are included.

GRAINS

COUNTRY	Output 1981 (10 thousand tons)	Precedence in the world
WORLD TOTAL	165,167	
United States	33,375	1
China	28,972	2
U.S.S.R.	16,841	3
India	14,490	4
Canada	5,026	5
France	4,470	6

COTTON (ginned)

COUNTRY	Output 1981 (10 thousand tons)	Precedence in the world
WORLD TOTAL	1,538	
United States	339	1
China	297	2
U.S.S.R.	295	3
India	136	4
Pakistan	75	5
Brazil	61	6

TABLE VIII

MAJOR MATERIALS COMMODITIES IMPORTED (1981)(+) BY CHINA

ITEM	UNIT	QUANTITY
Rolled steel	10 thousand tons	354.58
Copper and copper-base alloys	10 thousand tons	5.37
Aluminum and aluminum-base alloys	10 thousand tons	5.78
Zinc and zinc-base alloys	10 thousand tons	1.24
Rubber	10 thousand tons	14.94
Synthetic rubber	10 thousand tons	2.71
Polyethlene	10 thousand tons	12.02
Polypropylene	10 thousand tons	10.07
Polystyrene	10 thousand tons	5.60
Polyvinyl chloride	10 thousand tons	1.10
Synthetic fiber yarn	10 thousand tons	20.05
Of which:		
Polyamide fiber yarn	10 thousand tons	4.70
Polyester fiber yarn	10 thousand tons	13.56
Regenerated fiber yarn	10 thousand tons	2.12
Of which:		
Artificial silk	10 thousand tons	2.11
Coal	10 thousand tons	193.85
Sulphur	10 thousand tons	26.05
Iron ore powder	10 thousand tons	335.51

(+) *Statistical Yearbook of China 1981.* Economic Information and Agency, Hong Kong (1982).

TABLE IX

MAJOR MATERIALS COMMODITIES EXPORTED 1981 (+)
BY CHINA

ITEM	UNIT	QUANTITY
Rolled steel	10 thousand tons	70.31
Tin and tin alloy	10 thousand tons	0.56
Antimony	10 thousand tons	0.82
Coal	10 thousand tons	24.29
Crude oil	10 thousand tons	1,387.36
Refined oil	10 thousand tons	467.23
Tungsten ore powder	10 thousand tons	2.68
Antimony ore powder	10 thousand tons	0.31
Tires	10 thousand sets	45.22
Plywood	10 thousand tons	0.62
Paper	10 thousand tons	21.54
Cotton yarn	10 thousand tons	4.77
Rayon yarn	10 thousand tons	0.99
Marble plate	10 thousand tons	0.75
Plate glass	10 thousand m^2	371.52

(+) *Statistical Yearbook of China 1981*. Economic Information and Agency, Hong Kong (1982).

STABILITY 1982 CONFERENCE AND LABORATORY VISITS IN JAPAN AND KOREA

Choung M. Lee

INTRODUCTION

This report summarizes what I learned while on a trip to Japan and Korea between 15 and 29 October 1982. The primary purpose of the trip was to present a paper entitled, "Prediction of Motion of Ships in Damaged Condition in Waves," authored by myself and Dr. K. H. Kim of the David Taylor Naval Ship Research and Development Center (DTNSRDC), at the Second International Conference on Stability of Ships and Ocean Vehicles. The conference was held in Tokyo, Japan between 25 and 29 October 1982. The secondary purpose of the trip was to assess the status of ship hydrodynamic research in Japan and Korea by visiting a few selected academic institutions and ship research laboratories in both countries. The first part of this report covers the assessment of ship hydrodynamic research in Korea and Japan. The second part of the report covers selected details of the visits. The third part covers the highlights of the conference.

SHIP HYDRODYNAMICS RESEARCH STATUS

- Korea

This country, relatively little known internationally for its shipbuilding capability, is now the second ranking commercial shipbuilding country in the world. The shipbuilding tonnage in this country jumped from as little as 12,000 gross tons in 1973 to 1.2 million gross tons in 1981. Parallel with the rapid growth in shipbuilding, Korea's ship research capability has also increased at a rapid pace. There are five universities in South Korea which have active programs in naval architecture, and there is one government-subsidized ship research laboratory comparable to the major United States and European ship research laboratories. The ongoing research in ship hydrodynamics in Korea appears to be directed toward providing immediate ship design data for the shipbuilding industry. The Korean shipyards are eager to develop energy efficient hull forms with attractive prices which can induce ship owners in the Western world to build their ships in Korea. The three major shipyards in South Korea--Hyundai, Daewoo, and the Korea Shipbuilding and Engineering Corporation (KSEC)--are actively pursuing geometric series hull form development. Such efforts in series hull form development has long been discouraged in the United States and European countries due to their prohibitive costs. However, for a country like Korea which does not possess a historical data base in which to develop new hull forms and has affordable labor costs, the effort may be a worthwhile venture.

Other research emphasizes the improvement of small coastal fishing vessels and ship-hull design technologies, particularly for computerized ship design and the accumulation of model test data. Push barge systems and wave impact loads on bow flares are being investigated. One of the shipyards has been engaged in the development of air cushion vehicles for both commercial and military use. Two prototypes of 5 and 20 tons have been built and extensively tested in calm waters as well as in turbulent waters.

New facilities are being installed at the Ship Research Station of the Korea Institute of Machinery and Metals in the Daedok Science Town located about 100 miles south of Seoul. The major new additions are a cavitation tunnel, a wave maker, a numerically controlled propeller-model milling machine and a ship-model milling

machine. The Department of Naval Architecture of Seoul National University has just installed a towing tank of 117 m (length) x 8 m (breath) x 3 m (depth) which would be capable of towing a model up to 6 m in length. A wave maker is scheduled to be installed by the summer of 1984. This tank is larger than the one at the University of Michigan. With the departments modern computing facilities and equipment, it could conduct high quality ship model experimental research in the near future.

The number of graduate students in naval architecture has risen each year; there are about 100 studying at Seoul National University, Pusan National University, and Inha University in Inchon. There are about 30 graduate students from Korea majoring in naval architecture and ocean engineering in the United States who are sent there either by the government or by private shipbuilding industries in Korea. About 15 graduates are working on their advanced degrees in naval architecture in Japan and about the same number are studying in European universities. It is expected that within ten years the Korean ship hydrodynamic researchers will be major contributors to international technical conferences.

- Japan

Since the late '50s this country has enjoyed the indisputable position of being the top ranking country in commercial shipbuilding in the world. Its share of world commercial shipbuilding in 1981 was 34% which compared to the United States' share of 3.6% reflects an order of a magnitude of difference. However, most of the ship hydrodynamic researchers this reporter has met in Japan expressed grave concern over the decline in research support by the shipbuilding industries. The major reason is that, despite its lion's share of the world's shipbuilding market, the shipbuilding industry in Japan suffers a great deal from the overall reduction in the world orderbook which has resulted in 30 - 50% below capacity production for Japanese shipbuilders. Since the ship research community in Japan draws its support mainly from the shipbuilding industry through the Shipbuilding Promotion Association of Japan, the below capacity workload in Japanese shipyards means a direct reduction in the contributions to research funding. Furthermore, the Japanese government, foreseeing future world market trends, has been encouraging its shipbuilding industry to trim its shipbuilding capacity by 30%. Because of these conditions, shipyard hiring of naval architecture graduates has decreased which in turn has discouraged other students from furthering their studies in advanced degrees in naval architecture.

Despite the rather discouraging outlook, this reporter has not noticed any significant change in ship hydrodynamic research activities in Japan. It appears that the ship research community has adjusted to the decrease in the research funding level without significantly sacrificing its research productivity. One distinct difference between the Japanese ship research community and that of the Western world is the higher degree of cooperative attitude of Japanese researchers when challenged by foreign competitors. Cooperative research undertakings among academic institutions, private industry, and government laboratories are common practices in Japan. For instance, when there is an international conference of interest to the Japanese Society of Naval Architects, the Society selects appropriate delegates, supports their travel to the conference and lets them write a trip report in the monthly Society cooperative research bulletin. Even now when funding shortages are being experienced, activities seem to continue without much hindrance.

From the announcement of the 1982 fall meeting of the Society of Naval Architects of Japan, there were 48 papers written in the ship hydrodynamics area which, when

combined with the 17 papers presented at the 1982 spring meeting, makes a total of 65 papers written on ship hydrodynamics. If the papers presented in two other naval architects societies (the Seibu Society of Naval Architects and the Kansai Society of Naval Architects) are added, the total would be more than one hundred papers in ship hydrodynamics produced in Japan in 1982. The number of papers in ship hydrodynamics presented in the journals and the transactions of the Society of Naval Architects and Marine Engineers in the U.S. were less than 30 in 1982.

Typical subjects of common interest to the ship hydrodynamic research community in Japan are represented by the projects supported by the Ship Research Association (SRA) of Japan. The current projects of SRA are as follows:

- Investigations of deep-sea moorings of ocean platforms (SR 187)[1]

  Prediction of the behavior of floating bodies and mooring forces, and investigation of mooring elements.

- Studies on exciting forces and stability characteristics of ocean platforms (SR 192)

  prediction methods for sea environments,
  wind loads determined by wind tunnel experiments, and
  investigations of corrosion and fatigue.

- Studies on propeller-hull interactions to reduce stern vibration and noise (SR 183)

  preparatory experiments for full-scale wake measurements,
  prediction methods for forces on propeller blades,
  relations between stern geometry and wake distribution, and
  observation of full-scale propeller cavitation.

- Studies on design and construction of ships and ocean platforms for icy sea environments (SR 186)

  hull form development for tankers for icy waters, and
  basic experiments for ocean platforms for icy sea regions.

- Full-scale experiment of the Sirase in the North Pole seas (SR 186)

  design, manufacturing and purchasing of measuring instruments, and
  calibration and handling training for instruments in cold regions.

- Investigation of ship hull response in waves (SR 194)

  refinement of analysis of extreme waveloads on ship hulls.

From the foregoing, it can be determined that heavy emphasis is being placed on research in ocean platforms and, in particular, cold region research is being stressed. This is a natural trend for Japan which has to acquire a good portion of world orders in oil drilling platforms to keep its shipbuilding industry busy.

[1] This represents the Panel Number which is responsible for the project. The panel members are represented by researchers from academia, industry, and government laboratories.

Although the current slump in the shipbuilding market undercuts research funding in Japan, it appears that the ship research activities in Japan will continue to grow with its old vigor, particularly in the area of ocean platforms and surface ships. Recognition of the critical areas for future research in ship hydrodynamics is commonly shared by researchers in both the Unites States and Japan.

DETAIL OF VISITS

- Korea

Visits to the universities and ship research laboratories in Korea and Japan took place between the 16th and 23rd of October.

- Department of Naval Architecture, Seoul National University

There are nine faculty members and one visiting professor, who is on leave from the David Taylor Navy Ship Research and Development Center, and about thirty graduate students which includes three Ph.D. candidates, in the department. The major research subjects are prediction of impact waveloads on bow flares, motion of spar buoys, and drift forces on floating bodies. When the towing tank construction is completed, they plan to launch an extensive experimental research program on ship motion and hull-series development for fuel conserving ships. The tank is of fairly large size (117 m x 8 m x 3 m) for an academic institution. Equipped with a modern carriage and wave maker and strengthened by modern on-carriage computer capabilities, the tank can be utilized both for academic and industrial purposes.

- Ship Research Station, Korea Institute for Machinery and Metals (KIMM)

This modern ship research laboratory was established at its current site in 1978. The major experimental facilities are a towing tank of 203 m (L) x 16 m (B) X 7 m (D) equipped with a towing carriage of maximum speed of 6 m/s, a computer controlled flap type wave maker and a vertical planar motion mechanism, and a cavitation tunnel of interchangeable test sections of 2.6 m (L) x 1.45 m (B) x 0.7 m (D) and of 6 m (L) x 1.45 m (B) x 0.7 m (D). The maximum flow speed for the former test section is 12 m/s and 4.3 m/s for the latter. By 1986, plans are to have three additional tanks, an ocean engineering basin, a shallow water towing tank, and a high-speed towing tank. In addition to the hydrodynamic laboratories, the research station has a structures laboratory, a marine engine laboratory, and a deck gears and machinery laboratory. The total number of research staff members is 104. The major research subjects in ship hydrodynamics currently in progress are hull development for a 440,000 ton bulk carrier, development of analytical methods for ship hull designs, modernization of small fishing vessels, modernization of coastal transportation vessels, and optimum hull form search by wave pattern analysis. Dr. C. S. Lee, who obtained his Ph.D. from the Massachusetts Institute of Technology in 1979 and is regarded as one of the pioneering researchers in propeller theory, is the head of the Propeller and Cavitation Division. With a newly installed cavitation tunnel, he plans to take on ambitious research efforts in the propeller and cavitation area.

- Japanese Research Institute for Applied Mechanics, Kyushu University

This institute, under the leadership of the late Professor Tasai, has been well-known for its excellence in research in the area of ship dynamics in waves. The

major facilities are a towing tank of 80 m (L) x 8 m (B) x 3 m (D) equipped with a digitally controlled carriage (maximum speed 4 m/s), a wave maker capable of generating short-crested irregular waves, and a wind generator of 20 m/s maximum speed; a smaller towing tank of 60 m (L) x 1.5 m (B) x 1.5 m (D), in which the famous pioneering theoretical work of Professor Tasai on oscillating 2-D cylinders was confirmed; a wind tunnel capable of generating pulsating air flow with the maximum speed of 70 m/s; and a vertical inlet wind tunnel open to the air with a maximum air speed of 50 m/s and 3 m/s pulsating velocity amplitude at the mean air speed of 10 m/s. This wind tunnel is noted for its low turbulence level of less than 0.03%. The original objective of the establishment of this institute was to focus research on sea disasters caused by severe ocean winds and waves. Thus, the existence of unusual pulsating wind tunnels and short-crested wave generating capability is the result of this objective. The Kyushu region is well-known for frequent calamities caused by typhoons, e.g., the so-called "Kamikaze" occurred in this region. The current research activities in the ship hydrodynamics area are mainly focused on motion and waveloads on floating ocean structures. Some of these activities are: nonlinear hydrodynamic forces on ocean structures, motion and stability of floating structures, added resistance of ships due to waves, ship motion due to wind and waves, and dynamics of flexible cables under oscillatory slows. I witnessed an experiment on a vertically oscillated flexible pipe in a tank. It was fascinating to observe the unstable behavior of the pipe at certain critical frequencies. Professor Ohkusu, who became the director after Professor Tasai, is certainly going to expand their traditional reputation as one of the leading research institutions in ship dynamics in the world.

- Department of Naval Architecture, Kyushu University

This department is the second oldest university naval architecture department (next to that of the University of Tokyo) in Japan. Its reputation is well-recognized by the international ship research community. There are six chaired professorships and the same number of associate professorships. Two of the chaired professorships and three of the associate professorships are unfilled. In ship hydrodynamics studies, Professors R. Yamazaki and K. Nakataka provide lectures in ship resistance and propulsion and Professor K. Kijima in hydrodynamics and ship motion. The major facilities used in ship hydrodynamics studies are a towing tank of 118.6 m (L) x 2.7 m (B) x 5.5 m and 3.0 m (D) equipped with a carriage and a wave maker; a maneuvering basin of 28 m (L) x 25 m (B) x 1.8 m (D) with a rotating arm and wave maker; and a wind tunnel of 0.6 m diameter test section with maximum wind speed of 30 m/s. The current major research subjects are: the effect of propellers on rudder performance, propulsion characteristics in waves, numerical analysis of sloshing motion of fluids in a tank, and interaction forces and moments between ships in shallow water. Professors Yamazaki and Nakataka are the leading authorities in Japan on hydrodynamic interactions between hull and propeller and between propeller and rudder. Both Professors Nakata and Kijima have spent a part of their sabbatical leaves in United States universities (the University of California at Berkeley and the Massachusetts Institute of Technology) and are familiar with the current research status in the United States in ship hydrodynamics. This department, which has been known to be conservative in accepting Ph.D. candidate students, has at present no Ph.D. candidates. The faculty members expressed their concern over the declining trend of the shipbuilding industry in Japan which is the major reason for the lack of interest among the naval architecture graduates in obtaining advanced degrees.

- Department of Naval Architecture, University of Osaka of Foreign Studies

This department, founded in 1949, is a relatively young naval architecture

department for a Japanese university. There are four chaired professors, three associate professors, four lecturers (equivalent to assistant professors in the United States), and seven research assistants in the department. This department has a long history of research in viscous resistance of ships. Professor N. Tanaka conducted pioneering research in viscous roll damping in the late fifties providing valuable empirical formulae for estimating the viscous roll damping coefficient. This research, inherited and further explored by Professor Y. Himeno, is now regarded as the frontier exploration in establishing a theoretical basis for predicting the roll damping coefficients. The department's current research activities in ship hydrodynamics are the investigation of the relationship between stern geometry and wake distribution, turbulent boundary layers on ships, roll characteristics of bodies, and wave energy absorption. The investigation of the effects of stern geometry in wake flow is being conducted by Professor Y. Himeno, who spent a sabbatical at the University of Michigan in 1978-1979. This research is a part of a cooperative research program under the auspices of the SR-183 Panel of the Ship Research Association of Japan. Professor Himeno's approach is based on a systematic perturbation expansion of the flow with a careful examination of the geometric effects on the succeeding higher order terms.

The facilities related to ship hydrodynamics research are a towing tank of 770 m (L) x 3.0 m (B) x 1.6 m (D) equipped with a towing carriage, wave maker and wind generator; a circulating water channel of 6.55 m (L) x 1.5 m (B) x 1.0 m (D) with the maximum flow speed of 2.3 m/s; and a small plexiglass tank of 4.0 m (L) x 0.57 m (B) x 1.0 m (D) with a harmonic oscillator for investigating unsteady hydrodynamic forces on oscillating 2-D bodies.

- Department of Naval Architecture, University of Osaka

This department has five chaired professorships covering ship strength, ship construction, ship design, ship resistance and propulsion, and ship motion. Professor I. Tanaka and his three associates are actively pursuing research in 3-D turbulent boundary layers, the effect of suction near the ship stern, and flow behavior around ship sterns. As a member of the SR-183 Panel, Professor Tanaka's group is seeking a physical understanding of the scale effect on the ship wake distribution. The eventual goal of their investigations is to determine the relationship between the stern geometry and the near wake distribution. According to Professor Tanaka, the SR-183 Panel has conducted wake measurements at three different towing tanks on an identical model geometry and found significant differences among the measured data, and later learned that the differences could be reduced considerably by adopting a uniform data analysis method. The SR-183 Panel is planning to conduct wake measurements on geosim models of 3.5, 4.7, 7 and 12 m lengths. Such data will be valuable to United States researchers, and it is hoped that the data will be available to them.

In the area of ship motion, Professor Nakamura and his two associates are conducting investigations of added resistance and propulsive performance of ships in waves, power absorption from ocean waves, wind forces on and stability of ocean structures, wave exciting forces on ships, and simulation of responses of a moored body in waves. To examine the effect of wave diffraction on added resistance, they towed a restrained model with a parabolic blunt bow in waves. The measured results showed significantly larger diffraction effects than the predicted values from the slender body theory. Professor Nakamura's group has a narrow channel tank of plexiglass equipped with a wave maker at one end and a wave absorbing beach at the other end. This tank was used to validate the optimum 2-D geometries for wave power absorption obtained by the

theory of Dr. M. Takagi of the Technical Research Insitute of Hitachi Shipbuilding Company. The investigation was carried out under a cooperative program between Osaka University and Hitachi Shipbuilding Company. Five geometries were tested and the validity of Dr. Takagi's theory was confirmed. I witnessed a wind tunnel test measuring wind forces on an ocean platform. The aim of the test was to determine the degree of drag added by major components of the superstructure.

In the area of ship maneuvering, Professor Nomoto and his research staff (one of whom is currently spending his sabbatical year at the University of California, Berkeley) are concentrating their efforts on the problem of ship maneuvering in stern waves. They have already reported a series of theoretical and experimental investigations on the subject. They have used the so-called "Hogben's Wave Dozer" to generate a solitary large amplitude wave through which a ship model was towed at the same speed as the wave celerity. The wave dozer is an inclined vertical plate towed at a constant speed slightly above the water surface just ahead of a ship model. It was proven by Dr. Hogben of the National Maritime Institute of Britain that it can generate large amplitude second order Stokes waves. Professor Nomoto's group has a ship maneuvering simulator facility. It was installed with the support of the Ship Promotion Association of Japan and other funding agencies. Professor Nomoto proudly informed me that the analog device of the simulator was entirely designed and assembled by his graduate students and has proven to be as good as those of professional manufacturers.

The major ship hydrodynamic facilities of the department are a towing tank of 100 m (L) x 7.8 m (B) x 4.35 m (D) equipped with a towing carriage of maximum speed of 3.5 m/s and a pneumatic wave generator, an open air pond for maneuvering tests, and a maneuvering simulator.

- Department of Naval Architecture and Ocean Engineering, Hiroshima University

This department, which recently moved to a new campus on the outskirts of the city of Hiroshima, has a modern towing tank of fairly large size for an academic institution. The tank is 106 m (L) x 8 m (B) x 3.5 m (D). The tank is equipped with a wave generator and a subcarriage which moves sideways so that combined with the movement of the main carriage, it can generate one straight model motion in the tank. Such nonstraight motion of a model is necesssary to obtain the hydrodynamic coefficients associated with maneuvering motions of ships. Most of the towing tanks built in Japan within the last ten years are equipped with a subcarriage which can move ship models in the transverse direction while a main carriage tows the models in the longitudinal direction. No towing tanks in the United States has such a subcarriage system. Other hydrodynamic facilities of the department are a circulation water channel having a test section of 4 m (L) x 1.4 m (B) x 0.9 m (D) with maximum flow speed of 1.2 m/s and a narrow tank of 42 m (L) x 1.2 m (B) x 2 m (D) with a wave maker. All these facilities were installed in 1982.

The department has seven chaired professorships in marine hydrodynamics, ship motion, ship design, ocean environment dynamics, ship strength, material and welding, and ocean structures. Its Ph.D. program in naval architecture and ocean engineering started last year. As far as the number of chaired professorships is concerned, the department is next to that in size of the University of Tokyo. However, it is the youngest naval architecture department among the major national universities in Japan. The faculty members are relatively young compared to the other schools and have ambitious plans for their future growth in ship hydrodynamics research. The major ship hydrodynamics research activities in the department are directional stability of ships in waves, stern boundary layers and wakes, effects of stern shapes on wavemaking resistance,

power loss of ships maneuvering in waves, and stability of ocean platforms. Both Professors Kose and Mori recently spent their sabbatical leaves in the United States. Professor Nakato's work in ship maneuvering and Professor Mori's boundary layer and wake studies are well-known internationally.

GENERAL REMARKS

Compared to the United States, there are more universities which have naval architecture departments in Japan, and consequently, more students majoring in naval architecture. The experimental facilities are also more versatile and, overall, are more modern than in the U.S. Particularly, many of the towing tanks in Japan are equipped with wind generators and subcarriages which are virtually nonexistent in the U.S. The main reason for the existence of wind generators on towing tanks is based on the necessity to investigate wind effects on surface wave generation and the effects of the combination of wind and waves on the capsizing of ships. Although a wind generator was a fashionable attachment to towing tanks in Japan and in some European countries, it is not being utilized as often as before since it has been recognized that simulation of realistic ocean wind effects at laboratory scale is still an unmanageable scientific venture. However, its usefulness cannot be completely ruled out when it comes to qualitatively examining the combined wind and wave effects on capsizing small fishing craft and ocean platforms. The subcarriage system is a good substitute for more expensive rotating arm type maneuvering basins for commercial ship models. Some of the towing tanks in Japan have subcarriages set on a turning table such that the combined motion can generate the more realistic motion of a turning ship. However, a large rotating arm tank such as the one at DTNSRDC still has a definite advantage over a subcarriage system in obtaining data for high speed maneuvering ships such as naval ships.

Wind tunnel investigations on ships and platform models are more frequently used by ship researchers in Japan than in the U.S. The main reason, in the reporter's judgment, seems to stem from the fact that wind tunnel investigations were traditionally performed by the aerodynamicist in the U.S., whereas such a tradition is not as prevalent in Japan and, furthermore, after World War II aerodynamic research was not as active as ship research in Japan.

STABILITY 1982 CONFERENCE

This was the second conference on stability of ships and ocean vehicles. The first conference was held in Glasgow in 1976. The principle objective of the conference was to exchange information on technical advancements made in the area of stability and safety of ships and ocean vehicles in rough waters. The conference was attended by about 330 scientists and engineers from 18 countries. A total of 55 papers were presented at the conference during the four-day technical sessions. The main subjects of the technical sessions were:

- the fundamentals of stability,
- stability assessment,
- damage stability,
- stability of fishing vessels, containers, special ocean craft, and
- offshore structures.

There was a panel discussion on the Philosophy and Research of Ship Stability one afternoon, and on Stability Criteria and Regulation another afternoon. There were many lively discussions among the participants. The papers presented at the conference were

more oriented toward naval architects and ship operators. From the panel discussions, it was obvious that the need for a better understanding of the capsizing mechanisms of ships and offshore structures precedes the establishment of stability criteria for these vehicles.

Session I of the conference began with three papers termed "general studies." The first paper by Dr. Rusaas of Det Norske Veritas of Norway presented an assessment on the capsizing of the Norwegian oil drilling platform, "Alexander L. Kielland" which sank on 27 March 1980 in the North Sea. It was obvious from this paper how crude the stability design criteria for ocean platforms has been. This paper was one of the highlights among the papers presented at the conference. The next paper was one of the two papers from the U.S.S.R. The paper was concerned with a method of calculating heeling moments on fishing vessels with a small free board when gradual green water shipping on deck occurs. The method presented is a static calculation of a practical nature based on empirical coefficients derived from a test model conducted in a towing tank in Paris from 1966 to 1967. During the afternoon panel discussion on Philosophy and Research on Stability of Ships, another Russian paper on the question of rational criteria development for estimating the ship's dynamical stability in irregular waves was presented. The authors of both the Russian papers were from the Krylov Ship Research Institute, the biggest ship research institute in the U.S.S.R. The second Russian paper presented a statistical method for assessing a ship's safety in irregular waves. The paper did not offer many significant new advancements in this area.

Sessions II through V were held on the second day of the conference. Session IIb, chaired by Dr. Fujii of Japan and myself, was concerned with the stability of semidisplacement ships, i.e., planning crafts. The second paper by Dr. Baba, of Mitsubishi Heavy Industries, revealed an interesting finding through model experiments that the course stability of a semidisplacement type craft is improved by a spray strip since it raises the center of hydrodynamic side force. The paper by Dr. Takaishi of the Ship Research Institute of Japan presented a vivid process of a capsizing fishing vessel model in a towing tank. It was a useful demonstration of a physical phenomenon which should be taken into account in future mathematical modeling.

On the third day, a technical tour of the Ship Research Institute (SRI) of the Ministry of Transportation in Tokyo was conducted. SRI is the largest institute of its kind in Japan. However, in size and versatility in experimental facilities and technical manpower, DTNSRDC still enjoys superiority. One notable feature was a newly built ice tank in which ice breaking behavior and its resistance on ship models is being investigated. This new facility reflects Japan's serious interest in understanding ship and platform performance in icy waters.

Sessions VI through IX were held on the fourth day. These sessions covered damage stability, stability of special ocean craft and offshore structures, and stability devices. This reporter's paper was presented in Session VIa. On the fifth and last day, Sessions X and XI, covering broaching phenomenon and stability of offshore structures, were held in the morning and the second panel discussion on Stability Criteria and Regulations was held in the afternoon. The second panel discussion presented various stability criteria and regulations exercised in countries like Spain, Norway, West Germany as well as with the International Maritime Organization (IMO). Each country has its own stability criteria based on its past experience. Spain, for instance, determined its stability criteria for fishing boats based on a statistical analysis of ship losses in the past.

It is apparent that China is gradually becoming more active in international conferences of ship research and technology. There were five papers from China at this

Conference which represented almost 10% of the total papers presented. In contrast, only three papers from the U.S. were presented. The quality of the papers from China may not be regarded as high; however, they demonstrate that there is vigorous ships research activities going on there.

JAPANESE PROGRESS IN ROBOTICS: TOKYO CONFERENCE AND EXHIBITION

Nicholas A. Bond, Jr.

INTRODUCTION

International robotics conferences occur several times a year these days. In 1983, there were at least two big American meetings, one or two in Europe, and this one in Tokyo. The format is quite similar around the world, too; one usually finds concurrent scheduling of some dozens of papers, proceedings that fill one or more fat volumes, and enough lunches, buffets, and receptions to favor a lot of informal liaison. Scheduled to overlap with the Tokyo conference, there was a contiguous "Robot Exposition" where the observer could see two great halls full of working robots, and there were also postconference industrial tours to major Japanese application sites. Certainly the Tokyo Robotics Conference (12-13 September 1983) and Exposition (7-11 September 1983) provided a good opportunity to scan the present state-of-the-art in Japan, and perhaps it also afforded a glimpse of the what we can expect in the immediate future.

Japan is often credited as the world's major user of robots, and by official Japanese count some thousands of robotic devices are on-line right now, perhaps more than in any other country. How many of these should be counted as "true" robots is a persistent semantic controversy which will not detain us here. What is certain is that Japanese industry is an aggressive <u>user</u> of the "robotic" devices now available, however those are defined, and it has some unique capabilities and utilizations already under its belt. There are many anecdotes, but little firm data, on the extent to which robotic devices are responsible for Japanese industrial supremacy in such areas as automobiles, steel, watches, cameras, and consumer electronics. Perhaps a conservative view is that robotic techniques will be of gradually increasing importance for the next few decades; in some areas, they may be the critical factors in determining the economic viability of entire national industries.

Technical sessions at the Tokyo conference included 55 papers, of which the majority were reports of new or ongoing research. It was clearly a Japanese show with 39 papers from the host country; the U.S. had seven speakers present, and all the European countries together had only half a dozen items on the program.

GENERAL PRESENTATIONS

- Japan

A major review-and-projection paper by Y. Umetani (Tokyo Institute of Technology) and K. Yonemoto (Japan Industrial Robot Association) offered some of the standard positive predictions about robot technology and its complicated impact on modern life. But there were two unusual features: (1) rather than relying on vague Sunday-supplement prospects, the authors had actually assembled and tabulated certain empirical trends in Japanese robotics, and (2) they also projected <u>specific target years</u> for the completion of explicit goals. As an example of the empirical data, a graph of Japanese patent trends showed that, in mid-1982, the rate of new robot-related patents increased remarkably. Since the lead time between patent application and grant is about a year and a half, it appears that a simple time-line "patent index" reflects rather closely the rapid increase in the Japanese robot market which was observed early in 1981. The patent analysis also gave clear suggestions that practical shape recognition devices are <u>not</u> being widely

patented in Japan right now, and neither is new actuator technology. On the other hand, sensor technology is a very active area judging from the patent listings. Other statistical indicators confirm the sharp recent growth, too; there are nearly twice as many Japanese universities and national laboratories now doing robotics studies as there were only four years ago, and the number of supported professional investigators has more than doubled. "New" national-level research budgets in robotics are growing steadily at something like 20% a year, though the exact figures are often difficult to find because government grants are often strongly supplemented by private (and unpublished) company funding.

Last year, the Agency of Industrial Science and Technology published a comprehensive forecast and "goal" listing of the various technologies; from this document, Umetani and Yonemoto extracted goal-task elements which were related to the robotics domain. Each projected goal element also had an "importance" rating attached to it. This rating is presumably useful to industrial and planning authorities in Japan. A fragment of the forecast is shown in Table 1. While there are perhaps few surprises in the table, one thing stands out and that is the strong immediate emphasis on alleviation of dangerous or disagreeable work conditions. Considering the entire list, only a part of which is shown here, the mean projected time for "goal realization" is 1997. Self-repairing and "welfare" robots, again according to the Table 1 schedule, should not be expected until well into the next century. The self-repair and "silent maintenance" theme, incidentally, appears to engage Western technologists to a far greater extent than it does the Japanese scientific community.

Various other groups in Japan have produced robotics priority listings; for example, the Expert Committee in Long-term Technological Prospects of Industrial Robots (chaired by I. Kato of Waseda University) delivered the results of its Delphi-method study in May 1983. Scanning that report, a robotics researcher would not be greatly surprised to read that a larger and finer semiconductor image element is a worthy R&D topic, or that lighter, stronger, and more compact servo motors deserve intensive effort. But there are a few signs of East-West differences which may intrigue the American observer. To mention just one, the Japanese Delphi board experts did not perceive that basic theories of intelligent control, information processing, and software were very important, probably because for present Japanese applications adequate theories seem already to be available (if the process is simple enough, control models can be simple and still be effective). At the same time, the Japanese R&D people on the Delphi board knew that U.S. and European workers are concentrating large fractions of robotics effort into such theoretical areas; therefore, Japan should do so as well! Altogether, the Umetani-Yonemoto paper is one of the best short descriptions of present Japanese planning in robotics.

The Japanese Agency of Industrial Science and Technology is sponsoring a broad robotics program with half a dozen or so major categories: self-propelling locomotion, e.g., (vehicles that can climb a rough building wall), manipulation (high-reliability actuators), autonomous control (navigation and displacement modules), "tele-existence" (remotely controlled systems with "presence"), and so forth. Though no specific expenditures were disclosed, the program is a large and long-term one with nearly 40 professional investigators participating in laboratories around the country.

At the Electrotechnical Laboratory (ETL) in Japan's Science City at Tsukuba, robotics work goes back nearly 20 years. Some early devices produced there can still amuse and intrigue the casual observer. For instance, a "carpenter" machine was built that could drive nails, saw wood, and bore straight holes with a brace and bit. Several

ETL "hands" could exhibit sensitive tactile discrimination, and could place standard parts in containers with high accuracy. Automated garbage collection and other locomotion tasks were accomplished at the laboratory demonstration level back in the 1970s. At about the same time, one of the most advanced artificial hands of that era was produced. The hand could twirl a baton or turn a baseball. ETL built laser tracking systems that could extract the features and edges of certain 3-D objects at high speed. Large square boxes, for example, could be followed and "interpreted" in real time as they were pushed or tumbled around.

Gradually, the ETL approach to robotics changed. Instead of trying to build a machine that could, for example, imitate what a carpenter could do, the goals shifted toward designing for flexible man-robot "coordination systems" which would realize the intrinsic advantages of man and machine. The shift in approach is exemplified by a man-machine controller for a complex visual environment. A laser spot projector instantly measures the "feature points" of objects in a fairly complex field of view, and from these stimuli special software generates object images which can then be superimposed on a real or video scene display. A human employs such a system by "modeling the world" via the laser-software linkage with just enough enough accuracy for the situation at hand. In such an arrangement, the human controller does not have to enter numbers or code information according to the whims of some long vanished systems programmer; the interaction with objects is relatively easy and natural. Since ETL has also been working on torque-controlled actuators, the man-machine "world construction" aspects are being wedded to a highly accurate manipulation environment. Underneath all the visible system elements are developments in high-level manipulation languages. The final outputs of this work are expected to be systems which are conceived at an abstract level which demand more sophistication in both man and machine, but which can demonstrate genuine and adaptive "step improvements" in performance.

- United Kingdom

Another national summary paper came from P. G. Davey of Oxford University who reviewed Britain's "Robotics Initiative." The original idea was to pair small groups of academic research people with specific industrial companies. These "partnerships," which would be funded partly by the companies and partly by the British government, would direct effort to particular areas, eliminate overlap, and it is hoped, produce a "solid front." After the program had been running long enough for some results to be obtained, a critical Grantees Conference was held in 1982. Though the conference was a closed meeting, Davey and the government reviewers attending saw clearly that some preliminary achievements were already being realized in automatic assembly, in special "intelligent" sensors, and in heavily loaded manipulators. Davey presented the complete current list of U.K. partnerships sponsored by the U.K. Science and Engineering Research Council and it is shown in Table 2. Many of the work categories listed there are familiar enough, but a few novel items stand out: the robotic processing of meat, development of unmanned industrial tasks, and "error recovery" studies. Britain's status as a country with a declining smokestack industry base, but with advanced scientific and technological capabilities, make it a very interesting country to watch. In fact, Britain is a good test case for the hypothesis that robotic technology can be of most benefit to either declining or developing countries. As Davey observed, Britain's present push is toward the "second generation" of robotic devices. British planners believe that such devices will have to show some "common sense"--the same kind of common sense that people exhibit when they monitor factory production tasks today. Davey noted that production engineering cannot design "perfect" industrial processes so people have to be around to make the little adjustments, allowances, and small decisions required to keep

the imperfect processes going. Notable also was the rapid progress that Britain is scheduled to make: Davey's time scale for major benefits is on the order of five-eight years, which was one of the shorter forecasts heard at the Tokyo meeting.

- United States

In one of two general American papers at the conference, A. Bejczy of the California Institute of Technology Jet Propulsion Laboratory (JPL) described the remarkable decade and a half of space robotics work carried out at that facility. He showed a 1980 film clip which demonstrated how fast-moving the field is today. Only a few years ago, it was noteworthy that a manipulator system could be reliably and closely controlled in 3-D. Now, many analysts seek not only an an effective manipulator, they also want one that is natural for the human supervisor to use (the 1980 JPL version required numerical translational inputs and may have necessitated considerable practice by the human operator).

Though it is the world's leading producer of information processing equipment, IBM is not often a leading player in robotics meetings and there are few IBM manipulators or flexible industrial systems on the market. Many attendees at the Tokyo conference were therefore glad to hear a summary paper on IBM's Automation Research Project. Authored by R. N. Taylor and D. D. Grossman (Thomas J. Watson Research Center, Yorktown Heights, New York), the paper not only described IBM's technical work, but it also offered some general conclusions about projects in robotics based on IBM's experience in several laboratories. [For the American reader, a similar paper by Taylor and Grossman appeared in IEEE Proceedings, *71*, (7), 842-855, (1983).]

Perhaps the most important of these conclusions was noted early in the paper. IBM started out the project with the idea that robotics was mainly concerned with motion, and so the required motions, say for an industrial process, were carefully formulated and realized. Eventually, as the separate pieces of a flexible manufacturing concept began to be available, the key insight came: intelligent robotics is above all a matter of integration wherein many capabilities and information sources are linked together toward some goal. To accomplish the integration there must be computers, of course, but not necessarily a big central computer which controls everything. Software requirements may often turn out to be the most difficult to realize.

IBM's first prototype systems were not very practical, but after many slight improvements, such as in the sensor area, they evolved into the 7565 Manufacturing System which is now being evaluated in several industries and laboratories. At present, one research version of the system drives a hydraulic manipulator. There are many technical innovations in manipulator control. For instance, position control of each manipulator joint is accomplished by means of a dedicated card; the control computer can send position "goals" to these joint cards and it can obtain information to calculate present position errors. New position goals are calculated every 20 ms and the information is fully coordinated between joints. Support subroutines then produce the desired accelerations and decelerations. The arrangement is flexible enough to accept a large array of new requirements without extensive reprogramming.

As one might expect the IBM software organization is elaborate, and is believed to be one of the most advanced in the robotics domain. There are three main software elements:

- a programming component which permits interactive programming, possibly right at the work station,

- a work station interface that handles motions and sensors and that computes goal geometry from a coordinated "joint space" framework, and

- a supervisory system for managing the data processing terminals, disk drives, and other housekeeping.

AML, "a manufacturing language," was devised to meet system requirements; it was designed to be used by a wide range of people, not just by expert programmers. Transparency of software was also an important objective, too; IBM felt that operators as well as analysts should know what the system is doing at the detail level. Subroutines are provided for an assortment of robotics operations. The VISION subroutine, for example, can do a limited image analysis while a MOVE subroutine can move an actuator joint and MONITOR can schedule a series of jobs at a sensor.

IBM scientists conclude that an interactive programming language is a key provision in any really complex robotics effort. Apparently this standpoint has not always been so well articulated in some of the Japanese researches, and indeed it may be one of the major East-West differences in approach to robot development. It is hard for a nonexpert to say whether IBM is "ahead" or "behind" the Japanese robotics scene. A few Tokyo attendees were surprised at the rather standard data terminal used by the human operator in the IBM research configuration, and were perhaps disappointed in the system's primitive image analysis capabilities. In these days when computer graphics and perspective displays are rather well-advanced, the present terminal seemed rather unexciting. Another small surprise was that, in the 29 references listed at the end of the Taylor-Grossman paper, not one referred to any Japanese work in robotics (the same thing was true of all the other papers from American and European authors). Such total omission of Japanese research should be of concern both to Westerners and to the Japanese.

CRAWLERS AND SPECIAL VEHICLES

A staple of robotics meetings is the presentation of the latest thing in semiautomatic locomotion devices. Often the vehicles are designed to solve some obvious problem (taking food trays and equipment down a hospital ward), or to operate in a special environment (underseas, radiation hazardous, space, etc.). For years some observers have perceived an informal competition among countries, and among projects, on stair climbers, and ocean floor walkers. The Tokyo conference offered an interesting collection of vehicle studies and demonstrations.

- Mitsubishi Heavy Industries

Perhaps the most throughly validated of the vehicles described was the "Marine Live Growth Cleaner" produced by Mitsubishi Heavy Industries. The marine biofouling problem exists all over the world. At power stations using sea water in cooling towers, many kinds of organisms can build up in water intake tubes and in the heat exchanger piping. Among these are oysters, mussels, barnacles, starfish, and various microorganisms. Layers of material up to 10 cm thick are common near ocean inlets. Screens, chlorination, antifouling coatings, and electromagnetic field treatments have been proposed, but they all have limitations (see Table 3). The Mitsubishi design team decided to pursue the concept of an unmanned but controllable cleaning vehicle which would physically remove the underwater growth by brushing. The designers realized that mechanical removal was a rather primitive method, but it is effective, and if the waste material can be readily sucked up and removed, generally good results can be expected.

An early design decision at Mitsubishi was to provide a "clinging" capability for the cleaning vehicle by using axial water pumps; reaction forces to the pumped water should hold the vehicle firmly against any negotiable underwater surface regardless of wall orientation; also, four independent drive wheels were provided to give steerability along walls and channels. This concept was quite feasible. Integral buoyancy tanks were included to cancel the weight of the present vehicle when it was submerged. The "business end" or bottom of the vehicle has four rotating brushes, each one with its own separately controllable motor. There are also headlamps, color Vidicon cameras, and proximity sensors. The hoses and power cables operate through a reel control assembly and guide roller. All the television monitors and control switchgear are housed in a van which can be located on a special barge.

Many different brushes and scrapers were tried out; for fully grown barnacles and mussels, the best removal tool proved to be four loops of toolsteel mounted on a circular base. So fitted, the vehicle could sweep clean 5 m or more of "thick growth" per minute. For thinner larval growths, steel wire "stalk-brush" heads could sweep some 25 m per minute. The sketch in Figure 1 shows the general appearance of the vehicle as it looks when lowered into the water. As now configured, cleaning runs at one-month intervals are sufficient for the Japanese heat exchangers tested. The development and field validation of such a vehicle within less than three years is a remarkable engineering achievement. It will be noted, however, that the design is rather conservative with close human control being exerted from the nearby van; as yet, there is no sophisticated pattern recognition capability or "geometry control" in the system. It cannot run long by itself, change its brushes, alter its rate of progress, or recognize local variations in scraping conditions and requirements.

- Komatsu Technical Research Center

At Komatsu Technical Research Center, the project goal was to build a large underwater robot that could perform heavy work such as leveling an ocean bed for a drill rig installation (tethered and free swimming submersibles are good for inspection and maintenance tasks, but they cannot exert strong forces). The present version of the Komatsu Remotely Controlled Underwater Survey (ReCUS) is 15 m long, has an air weight of about 26 thousand kg, and "walks" on its eight legs at speeds up to 242 m per hour. The legs can be independently extended and retracted; both the inner and outer frames can "slide," and a turntable at the center of the machine can turn by swinging the frames. Figure 2 gives a cross section of the ReCUS body, and the heavy construction of the machine is evident in that view. Submarine floor height differences up to 2 m can be accommodated.

When ReCUS is commanded to walk or turn, a sequence of leg actions gets under way. Figure 3 schematizes the sliding and leg activations for a straight walk and for a stationary turn. A swing of a maximum of 22.5° can be negotiated in any one turn, and the typical walking "step" is about 2.5 m. "Posture" is automatically controlled within a degree or so by gyro reference.

An interesting "clear sight device" for viewing the ocean bed is a major feature of ReCUS. The device is supposed to enhance TV and camera images of objects in turbid water. There is a central sealed unit filled with clean water with three color TV cameras and three film cameras looking through the water and the bottom glass. Figure 4 shows the clear sight configuration.

ReCUS is believed to be suitable for a variety of heavy underwater tasks: pipeline trench digging, excavation, drilling, placement and moving of structures, and so forth. Figure 4 depicts one rubble removal configuration. The concept is a working bogie to run on rails which are attached to the firmly situated ReCUS; the bogie might be designed to accomplish rake and roller operations and to transfer large quantities of material. Manipulatable "walking" requirements can be exploited for operational purposes; thus, the turning sequence could drive a roller or smoother during the "sliding" phases of the turn. (The computer integration of such tasks is an obvious extension of the ReCUS project.)

- Security System Association

As one of the most crowded and earthquake-prone countries in the world, Japan has experienced many great disasters. The 1923 quake officially killed 156,000 people in the Tokyo area, but the human toll was greater than that and much of the city was flattened. Fire hazards can still be severe, and there are unacceptably high casualties among residents and firefighting personnel. While Japan has apparently produced no practical firefighting robots yet, the Security System Association, in association with the Tokyo Institute of Technology, has done some requirements studies which delineate the problem. The work was reported by A. Kobayashi and K. Nakamune. Present thinking is that as many as five different "disaster robots" may be justified for complex urban environments. For each one of the five classes, the constraints more or less drive the design concept. Sometimes a small and cheap vehicle can be envisaged, say for the inspection of a critical area for gas leakage, but a manned rescue vehicle would necessarily be complex and expensive. In the informal discussion, one attendee proposed that, for large high-rise towers, the possibility of robot fire extinguishing, inspection, and rescue could well be part of building design, just as window washing and utility access are considered now by architects. Tracks and sensor arrangements would be as carefully inspected as are the structural and sanitary elements in present building practices. It would then be unnecessary for extremely tall ladders to be the principal means of access to the upper floors of a building. Table 4 shows the systems analysis which appears to reflect Japanese thinking on the subject. (As long as ten years ago, the U. S. Navy Civil Engineering Laboratory at Port Hueneme, California, was working on a small firefighting tractor.)

- Hitachi Engineering Research Laboratory

The "transformable crawler" from Hitachi Engineering Research Laboratory (Tsukuba Science City, Ibaraki, Japan) has the ability to change its external shape as a function of the terrain conditions it meets. This transformation is accomplished by means of an ingenious "planet wheel" addition to the usual driving track. Figure 5 shows how the vehicle changes its shape when going up or down steps. The planet wheel moves along an elliptical orbit which has two focal points at the centers of the main and sub wheels. While approaching the first step of a stairway, the planet wheel would be slightly high and "in front;" after gaining a foothold on the stairs, the planet wheel would move itself to the back of the vehicle so that a low "flat tank" profile could be realized offering maximum stability during the climbing phase. A reduced-scale working model was shown at the conference; it is now being scaled up for realistic evaluation trials on stairs, ramps, and obstructed areas. A key element in eventual application will be system provisions for estimating whether the vehicle can negotiate a path that is commanded but that is variously obstructed. According to the Hitachi movies, the prototype vehicle seemed to "recover" well when it "fell back" from an unsuccessful climbing attempt on a stair or steep ramp.

- Energy Research Laboratory

A "remote maintenance" requirement was the motivation for the Hitachi hybrid locomotion vehicle. As in most countries, there is pressure in Japan to reduce the radiation exposure dose of nuclear plant personnel. Thus people cannot stay long in a primary containment vessel to do inspection and maintenance tasks; such work either must be done from remotely controlled units, or by "intelligent" robots. Regardless of the specific configuration, mobility is a prime requirement as there will always be stairs, ramps, and narrow passageways to negotiate. Static mobility is important, too, as an inspection vehicle often has to remain still while on ramps and uneven surfaces; it will often be carrying Vidicon and other payloads in the 100 kg range.

N. Ozaki, M. S. Suzuki, and Y. Ichikawa were the technologists who reported on the current status of the Hitachi vehicle. The prototype has five sturdy (about 25 cm diameter) legs, and each leg is fitted with a wheel and a central supporting rod. There are 4° of freedom on each leg: lifting, steering, wheel revolution, and wheel shifting. Each degree is driven by an independent motor. Control algorithms for driving the vehicle around are organized hierarchically. Desired traversal paths are broken down into straight lines and turning points; then, subroutines compute the instructions for each motor. To step over obstacles or to climb stairs, "ordering" production rules ensure that conflicts can be resolved, say, in situations where two or more legs encounter a stair or obstacle at the same time. Tactile and floor sensors are on each leg, and the whole vehicle is stabilized for tilt angle to within 5°.

Performance trials on the Hitachi prototype were encouraging. The maximum driving speed on a level floor was 35 cm/sec, though in typical operation the vehicle would go perhaps half that fast. Ramp and stair climbing capabilities of the prototype were probably suitable for many nuclear plant environments: slopes up to 15° could be climbed, and it took on the order of a minute for the machine to climb one step on a standard stair and to settle down in a stable state. To orient all five wheels in one commanded direction, seven seconds of central computation time were needed. To set up a pivot turn about a designated point on a level floor takes about ten times that long. No doubt some of these performance features could be improved by relatively simple means, such as by increasing the torque of the stepping motors in order to climb steeper ramps. Since nuclear inspection is not usually time critical, the Hitachi prototype will not need many improvements before it is ready for a realistic nuclear plant evaluation.

- Mechanical Engineering Laboratory

"Melchair" is a wheelchair project for disabled persons. It has been pursued for the past four years in the Mechanical Engineering Laboratory [Agency of Industrial Science and Technology (AIST) under the Ministry of International Trade and Industry (MITI)]. The chair is a part of the general patient care robot project called Melkong. In their report, E. Nakano and N. Koyachi focused on the locomotive engineering of Melchair. Omnidirectional Vehicle I (ODV-I) was the first working version. When tested a couple of years ago, it showed good smoothness, controllability, and positioning accuracy on a flat laboratory floor. But it took a "lot of engineering" and much machinery to accomplish all the motions (four motors were required, two for driving two wheels and another two for steering four wheels), and the case enclosing all the hardware was probably too large to be practical. After some further studies, a new and more compact ODV-II design has been devised, and it now requires only two motors: one for driving two wheels and one for steering four wheels. The key design features include a differential drive gear arrangement and a system of clutches for steering. There are three "modes" of

operation: omnidirectional mode, car mode (straight-looking rear wheels, but differentially rotating front wheels), and rotation mode (all wheels turning the vehicle about a central axis point). At the conference, films of the ODV-II showed a smoothly running vehicle in a hospital-like environment. The present control concept has everything the operator needs in a right-hand arm as shown in Figure 6. An electroluminescent panel, joystick, track ball, and a ten-key locomotion setting unit are all to be located on the arm. Undoubtedly, later ODV's will have more compact mechanical arrangements below the seat, will have ergonomically evaluated controls on the arm, and will have lifting facilities so that a handicapped person could place himself/herself closer to a keyboard, machine tool, or other work site. A few years further down the R&D road, chairs like this might have remote controls directly linked to remote controls on the Melchair arm, and might also be connected to machinery like lathes, mills, loading equipment, or "man amplifier" manipulators. There are also many possibilities for aided medical assistance to people who must be monitored continuously. With a Melchair, such patients could have some mobility even under a strenuous monitoring discipline.

- Osaka University

Osaka University investigators have been studying the control dynamics of a biped robot, and are believed to be among the world leaders in this field at the moment. F. Miyasaki and S. Arimoto summarized some recent progress. Biped locomotion is often intrinsically unstable. If the numbers of degrees of freedom and the number of actuators is the same, then such a system might be controlled by feedback techniques. But if the degrees of freedom become significantly larger than the (controllable) actuators, then overall stability cannot be realized by the vehicle itself. How, then, might a practical biped machine be realized?

Mikasaki and Arimoto proceed by separating the "unstable" or upper body center-of-mass mode from the other modes. This can be done because of the longer time constant of the upper body translation of the center of mass. Then, "smaller" relative motions near the ground are taken as the fast actuator modes. The slow mode computations produce the desired trajectories of joint angles and angular changes, and these are then realized by the bank of fast speed actuators at the limbs each of which is feedback controlled. The control system logic is summarized in Figure 7.

Experimental evaluation of one laboratory biped (IDATEN-II) at Osaka produced stable behavior with a 7° of freedom control model. Figure 8 is a sketch of the Osaka biped robot which must be one of the mechanical devices that best emulates human walking behavior. The Osaka project is now adding "learning" capabilities to the present laboratory model.

- Ishikawajima-Harima Heavy Industries

Ultrasonic devices play an important part in nuclear inspection, and their technology is highly developed. A major Japanese company in this domain is Ishikawajima-Harima Heavy Industries (IHI). In a typical setup for analysis of pressure vessel welds, a specialized machine rides a (preinstalled) track and a rotatable detector module records flaw indications along the weld; a pneumatic cylinder gently presses the detectors against the shell. A similar arrangement is used for looking at RPV nozzles; in this case the device rides on a ringtrack which is mounted on the nozzle. Most machines of this sort are remotely controlled once they are placed on the tracks, but humans still have to set and calibrate them and transport them to the test sites; activation times must be kept as short as possible to reduce human exposure in radiation hazardous areas.

Magnetic devices could, in principle, move around over ferrous surfaces without track guidance and thus they they might afford more flexible and "intelligent" inspection services. Ishikawa-Harima (IHI) has been doing development trials on two types of track-free locomotion devices. One of these, called a "step scanner," uses a double deck structure; each deck has four little feet and the whole machine walks by the action of stepping motors which activate the feet. Both decks are connected to a central rotation bearing, and so the rotation angle between decks and hence the direction of movement can be precisely controlled. A second design uses a flat scanner assembly frame wheel which is mounted on four magnetic wheels. Each wheel is driven independently by its own motor. Such a vehicle can be guided by coordinated speed changes at each wheel; but the wheel slippages are significant and errors are often cumulative.

Precise position control is essential for critical inspection work with such free moving vehicles, and IHI has formulated two schemes for managing the problem. One uses a center-located measuring wheel with sensors which can read the extent of measuring wheel deviations from preprogrammed courses. A second navigation control idea, and technically a more promising one, employs a moving laser which is mounted on the inspection vehicle. By means of a tracker table which is equipped with photosensors and precisely located at a master datum point, the bearing of the moving element to the base point can be accurately known. For short distances, location accuracies to less than a millimeter were achieved in a laboratory setup. Provision of laser navigational facilities would be impractical for some of the "ring" inspections now done by special machinery.

As a quick evaluation of ultrasonic inspection robotics, it seemed clear that tracked special machines will remain the principal means of ultrasonic nuclear environment inspection for some years, with occasional changes to laser-guided or other kinds of free moving vehicles when certain conditions (e.g., long straight welds) are favorable. The IHI speakers did notice something that could be done fairly quickly, and that is to "robotize" the placement of existing inspection machines onto preexisting tracks. This might be done within the present state-of-the-art. If so, humans could escape even the short exposure times now required for device insertion and removal.

- Fukuoka Children's Hospital

From an engineering standpoint, the human finger is in several respects inferior to a robot finger. A real human finger takes at least a few milliseconds to transmit a signal from one neuron to another, and nerve conduction velocity is on the order of 50 m per second. A typical feedback loop in a finger requires some dozens of milliseconds. Human finger joints themselves are often not really spherical, and some are quite irregular. In the best robot arms, spherical bearings are often engineered to have very little backlash; switching delays can be less than a millionth of a second, and signal conduction proceeds at the speed of light. Yet real fingers are clearly better for some tasks and are more flexible in all tasks. So just what is unique about the human finger? If we knew, conjectured S. Himero and H. Tsumura (Fukuoka Children's Hospital, Fukuoka, Japan), then we might build much better robots. Their project has performed a very detailed comparison of real and robot finger capabilities.

A real finger can be modeled as four pharangeal bones and three interpharangeal joints. There are five tendons or actuators which are attached to the bones and which transmit muscle contraction forces to the bones. Careful analysis of the degrees of freedom in a real finger suggested that only four real degrees of freedom exist: Z axis and Y axis rotation in the joint proximal to the hand and Z axis rotation in the two distal

joints. All the other possible rotations are constrained. For example, if the tip of the finger is pressed to one side (in the Y axis), the "recovery moment" of the countervailing force equals or exceeds the applied force and thus the finger does not move (within load limits).

Given four effective degrees of freedom and five actuators, a very large number of "solutions" to force delivery and force resistance requirements can suffice; theoretically, the number is infinite. This means that a person can specify one or two muscle forces and the rest of the system will accommodate in a number of effective adjustments. Another extraordinary feature of real fingers is the tonus or stiffness control at the joints. The Fukuoka model equations show that when an imposed objective force T is applied to a finger without any changes in position or force, the distal bones are strongly pulled against proximal bones. The increased stiffness which results is handy when heavy loads are to be manipulated, or when extremely precise timing of the stiffness and control are required (e.g., putting "spin" on a thrown baseball means a brief "stiff torsional" period to provide velocity followed by an even shorter "slinging" angular acceleration of the ball). When stiffness is not required by the situation, real human fingers lower the tonus. Another function of human finger tonus is to increase the linearity of actuator tendons. In a nulling servo system, as the goal state is neared, the intensity of the signal is weak and it is thus apt to be nonlinear and lacking in precision. But with an agonist-antagonist torque system where one force is counterbalanced and overridden by a countervailing force, the (command) agonist range of output will be near the central linear part of the input-output curve, and control precision will be maximized. Agonist-antagonist modes of action also serve to reduce backlash when such reduction is functionally necessary, and they and can help prepare for anticipated heavy loads.

Himeno and Tumura postulate a hierarchical control system. At the "top" or brain level, decisions are made about controlling either muscle length or muscle tension. Suppose the message is to control force in one actuator and tension in four other actuators. This message, along with servo gain information, is sent to "lower" control units, perhaps in the spinal medulla. These local controllers adjust their own slave outputs and coordinate them with other instantaneous outputs. In a human, this arrangement facilitates processing because so much is done "automatically." But the Fukuoka work has several implications for practical robotics design, and according to informal comments at the conference, the joint tonus concept is now being pursued in at least one Japanese manufacturing company. Nobody thinks that direct imitation of the human physiology would be feasible or desirable, but starting from the human model might assist in working toward a practical manipulation requirement.

- Electrotechnical Laboratory

At the Electrotechnical Laboratory (Tsukuba Science City, Ibaraki, Japan) effort has been directed to the design of a torque controllable manipulator. K. Takase, T. Hasegawa, and T. Suehiro are the investigators. Various arm configurations were tried over the past few years. The two best arms now under examination are self-balancing and use direct drive motors for most of the actuation. Among the supporting systems for the manipulator are a novel servo arrangement and a motion-description language. Performance characteristics are already very good: position accuracy to less than a mm, force control tolerance within 100 or 200 g, and practical acceleration in the order of 2 m/s with a 10 kg payload. [It is noteworthy that certain other research robots, such as the French one at Laboratoire d' Information pour Mécanigue et les Sciences de l'Ingénieur (IMSI), are supposed to achieve similar performance in the near future. (See J.F.

Blackburn's article in *European Scientific Notes*, ONR London, *37*, (5), 169-172 (1983.)] Figure 9 shows the general configuration and the placement of the motors. It is one of the most precise manipulator arms in Japan right now and is being used for control studies at Tsukuba.

- Power Reactor and Nuclear Fuel Development Corporation

Perhaps the most engaging paper title at the conference was the one offered by a team from the Power Reactor and Nuclear Fuel Development Corporation (PNC) Ibaraki, Japan. Their paper on "Servo Manipulator Having a New Multijoint and Ingenious Wrist" had nine authors and was read by H. Kashihara. The "ingenious wrist" has an additional degree of freedom so that the wrist (really the middle arm) can both bend and twist, and can do these actions in a far wider range than a real human arm. Slave motions which might be accomplished by arm and shoulder movements in a master-slave system were engineered to be driven by master signals from the operators wrist and fingers only; this arrangement was designed to reduce operator fatigue over a long manipulative sequence. The general two-arm setup can be viewed in Figure 10. From the operator's standpoint the layout seems to be "handier" and more convenient than are some other well-known master-slave controllers such as the SPIDER underwater system. As seen in the figure, the operator sits in a chair, the controls are lower than "actual arms," and so the operator should feel less constrained and surrounded by equipment. (A SPIDER operator is completely encased and "surrounded".)

The present slave arm arrangement has three main blocks or segments: top of arm to elbow (1 to 3 in Figure 11), the "ingenious" lower arm which can flex 75° (5 and 6 in the figure, and the bottom-wrist rotatable "hand" (7 and 8). Human engineering of the master grip has begun, and it is believed that improvements can be made in the present model. Right now, though, performance parameters are quite good: horizontal extension moves can be done at up to 75 mm/s, vertical and wrist rotation can swing at 8°/s, and there is a tong grasping power of 30 kg. Researchers in man-machine interface will probably be watching the eventual control configuration that PNC adopts for this system; there are few manipulators with widely bendable arm segments and nobody yet knows what the best controller device will be.

- Chuo University

An ideal tactile sensor for a manipulator hand would be light and compact, would accept a variety of loads, and should fit naturally into automatic schemes for object identification and placement. A sensor head project at Chuo University utilizes imbedded Hall integrated circuits (IC) elements in an elastic medium in order to gain object information. In the prototype version there are 20 Hall IC's and they are arranged opposite 20 fixed magnets (Figure 12). Deformation of the elastic material by a gripped object causes changes in the magnetic flux, and these changes can be read out. Even with only 20 elements, some object discrimination can be achieved; line fitting procedures can decide whether a columnar, square pillar, or prismatic shaped object is being gripped by the sensor head. Once this electrical sensor information is processed, then mechanical actuators can be commanded to grip the object with any desired power (pneumatic cylinders are used in the present setup). Experimental runs show acceptable control tolerances, at desired force, on a sample of regular polygonal objects. An obvious extension of the Chuo work is further sensor miniaturization and perhaps more sophisticated image analysis and control software behind the sensor head. The system is probably good enough right now to be considered for some transfer tasks on simple parts.

- Science University of Tokyo

Flexible control arms may be inevitable in robots that have to handle heavy payloads with light manipulator structures. The usual control models often assume the rigidity of arms and rapid damping of undesirable vibrations. Basic research at the Science University of Tokyo has been exploring the control of a two-piece arm wherein one arm segment is rigid and the element closest to the load is flexible. Professor T. Fukuda is the project leader. A two-dimensional motion model has been pursued far enough to give encouraging results. Strain gauges on the flexible arm sense the vibrations and bending moments in that member and normalized mode and time functions are estimated as inputs to a servo model. Experiments proved that the addition of such a control loop sharply facilitates the adjustment of the system to vibration caused by large rotational activity. At least in the two-dimensional laboratory case, the setup can exert a constant contact force between the tip of the flexible beam and a wall. Application of this technology to contoured surfaces seems to be a near-term possibility. A refinement of the flexible arm studies had to do with failure detection and fault tolerance within the system; with the present design "graceful degradation" would result for at least some failures. In all likelihood, provisions of this sort will be necessary for the 24-hour factories of the future.

- Kyoto University and Toyoda Automatic Loom Works

One of most general articulated hand control models was described by a team from Kyoto University and the Toyoda Automatic Loom Works (TALM). The model can accept any reasonable number of fingers and joints and in fact was realized in the development work with a hand of three fingers and 12 joints. It is necessary for the system to know accurately the degrees of freedom that exist for a given handling task; also, the analysis separates joints into passive (without actuators) and active elements (with actuators). Grasping of a (well-defined) object is achieved by "rocking" the active joints by commanded small displacements; during rocking, the object space is in free space constraint. When the object is not being rocked but is moved about, it is in mobile space. Formulation and solution of control equations indicated that the system should still be able to hold an object securely when sudden external forces are encountered. Transfer tests with a light cylindrical load were encouraging, though the present hand hardware is so "breadboardy" that it would not be applied just at present (remote dc motors are attached with cables and pulleys to the finger joints). Servo analysts will probably be interested in the TALM methods for determining the two "spaces," and for measuring the instantaneous redundancy of a multifinger control system.

- Osaka University

An application paper which created something of a stir at the Munich Pattern Recognition Conference last fall was presented again at Tokyo. WIRESIGHT, developed at Osaka University, was conceived as a major aid to the automation of electrical wiring operations. To solder automatically the wires from a capacitor or transistor, for example, an automatic system has to know precisely the 3-D location of the wire ends or "tails" on the part. WIRESIGHT operates by taking two pictures of the scene, first when illuminated by a fixed point light souce S, and then when a second light source S' is turned on. Under reasonable resolution and wire pattern conditions, the shadow geometry permits straightforward calculation of wire end coordinates. Automatic interpretation of images is done by storing the background image (without test object) for each light source, and then applying a "thinning" procedure to compute the several wire end outlines and coordinates. At present a 256X256 pixel Vidicon camera is being used, and X,Y, and

Z coordinates are accurate to a tolerance of less than 1% (a mm or less); this is close enough for some state-of-the-art manipulators to grab the wire ends. If necessary, even higher accuracies could be expected from a finer grained Vidicon and from wider light source separation . Figure 13 depicts the general setup.

- Electrotechnical Laboratory

One of the leading centers of Japanese robotic vision research is the Computer Vision Section of the Electrotechnical Laboratory at Tsukuba Science City in Ibaraki, Japan. Professor Y. Shirai, M. Oshima, and K. Ikenchi have been working for several years on schemes for reducing the amount of computer search time needed to identify objects. One of their proposals is to compute the Extended Gaussian Image (EGI) of an object. An EGI is the distribution (in length and direction) of surface normals. Looking at a cylinder that is slightly tilted on the Z axis, but not in X or Y, the EGI can be depicted as in the top part of Figure 14. After imposing constraints on possible lines of sight and the principal axis of EGI points on the image plane, the recognition system compares the length of EGI arrows as seen with a set of stored EGI models; the model is chosen that minimizes a difference function between the observed and stored models.

An extension of the approach obtains a surface normal at every pixel of a given image; this is called a "needle map," as the normals can be visualized as needle vectors. There is also a stored "GEOMAP" set of object needle map models, and again difference integrals are computed to make a classification. A constraint in this approach is that the (observed) object is assumed to be situated in its stable or "best" resting state, and it may be difficult to guarantee that condition. In the Figure 14 illustration, the system probably would eliminate the cylinder but could not distinguish between the two rectangular blocks. These procedures can also be planned to operate in hierarchical fashion.

A "range data" analysis of fairly complex scenes tries to move from the complexities of a real scene into an abstract depiction of a scene that can be stored in an economical form. At the Electrotechnical Laboratory, one complete system for doing this uses a rotating light-slit projector, with an image being recorded for many discrete directions of the light beam. A "stripe image" of the scene is stored for further "region" processing. Thus, regions with uniform light intensities are identified as separate surface elements and are then possibly merged with nearby "similar" regions. The regions themselves are automatically classified as planar, curved, or other. Curved regions then are blended together if they can be made to merge "smoothly." These merged curves, together with planar areas, are termed "global" regions. In the final stages of the process, curved regions are fitted with quadratic curves and the relations between globals are also stored in such terms as distance and convexity. Figure 15 illustrates this kind of analysis with a topical scene used in the laboratory. The resulting descriptions can also be used for "learning" the characteristies of known objects. Statistical methods for assisting this kind of "teaching," and for evaluating the usefulness of it also are under study at the Computer Vision Section.

It is interesting to watch the progression from a near-realistic stripe image to a property-region formulation. In Figure 15, the vessels-and-tongs stripes can be transformed into the regional map in the lower part of the figure. Sometimes a "kernel" or high information part of a complex scene can be identified. If so, the matching scheme can ignore most other scene constituents and can look only at those (stored) models which have the kernel aspect. These models, and these only, will then be searched "near" the kernel for abstract property similarities. Such processing should narrow the search space considerably.

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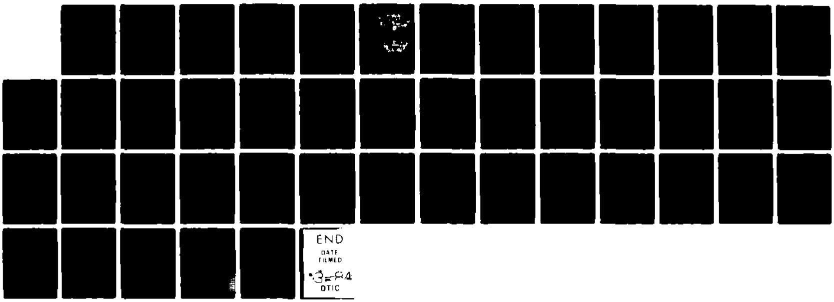

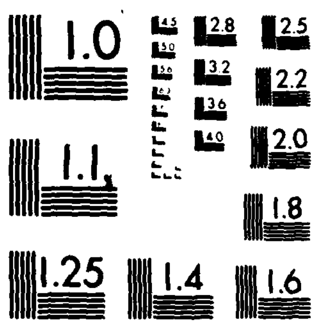

MICROCOPY RESOLUTION TEST CHART
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- Odetics, Incorporated

Odetics, Incorporated (Anaheim, California) contributed the main American entry in the vehicle description department. The Odetics "Functionoid" robot was shown via a series of quickly-paced slides, so that its capabilities could be seen in near-movie fashion. A six-legged spidery configuration, the Functionoid vehicle meets many requirements such as mobility, strength, stability, compactness, and self-contained power. The vehicle usually walks by lifting three articulated legs which advance while the other three legs support the structure; ordinary human walking speeds can be attained. It can carry nearly a ton of dead weight load and still walk; one series of slides showed the device pulling up the back end of a pickup truck on a static lift. In a "thin" configuration, the machine can "tuck up" its legs so as to walk itself through a door only 27 inches wide . Remarkably, nearly all the main computations and data flow distribution controls are on board the vehicle itself. There is a special central computing and bussing scheme, and each leg has its own computer. Like the other robotic vehicles developed around the world, Functionoid probably will be engineered and adapted for some specific task environment (construction, mining, agriculture) if it is ever used as a practical device. The Odetics technologists believe that something close to the present version, but perhaps with more computing power and added sensors, might be economically justified in many settings.

ROBOT EXPOSITION

To the nonexpert viewer, a first impression at the two halls of robotic machinery and systems was of "clean" but "heavy" applications. This probably was because several large systems for handling car body assembly were near the entrances. All of these seemed to work well with the bodies turned precisely on schedule and with many "welds" applied to frames and doors. "Painting" rigs (equipped with compressed air and streamers on the nozzles) were quite numerous, too; according to informants, most of these operated on "teach-in" information from a human expert painter but model-based inputs are likely to supplant simple follower spray devices in the near future.

Whether one calls them robots or semiautomatic machinery, many of the machine tool attachments were most impressive. Several manufacturers offer "lathe robots" which can be quickly programmed from a handheld board and which can handle standard work pieces with impressive dispatch. Several hundred memory steps are now standard in these systems with better subroutine calling and branching capabilities than those of a few years ago. The practical "hand" or gripper capabilities on view were, of course, far less complex than some of those described earlier in this report. The ones in practical use usually operate pneumatically and are engineered to a specific part handling task.

Assembly robots now on the market guarantee fractional millimeter repeatability for small (< 12 kg) parts, with similar accuracies claimed for screw tightening, pressure insertions, and sealing. For heavy loads (100 kg) the accuracy declines to a mm or so, but a few systems are starting to have a "visual vernier" for more exact location. If a part is fairly well situated, then one or more circular holes and straight edge segments can be used to adjust the part for final gripping. A working demonstration had an imaging device which located gear pieces by computing hole centers. One of the most accurate assembly robots at the show, or for that matter in the world, was the SUWA Seikosha Model SSR H414-H. This machine installs parts in Seiko quartz watches with .016 mm repeat accuracy. Sometimes sheer esthetic factors can be noticed. A beautiful robot to watch was the Nachi-Fujikoshi 8000 which fixes rear windows in Toyota automobiles. The great arm smoothly sweeps a fast arc while holding the window with two suction

heads. As it nears the window frame, the arm slows and accomplishes a smooth "exponential" flare as the glass goes into the frame. Watching this machine in action, an observer might think of a perfect landing of an airplane.

Some manufacturers displayed special subsystems or components that conceivably could be used in any number of robotics applications. Among these was the Harmonic Drive Systems whose ingenious gearing arrangements are already being used around the world. Rotational input to a toothed elliptical "wave generator shaft" causes a wave-like motion to be imparted to a "flexspline." Because it is mounted in a fixed circular spline, each full input revolution of the input driver delivers only a very much slower (and opposite) rotation to the flexspline. Thus, extraordinarily high gear reducton ratios are achieved in a single stage with very low blacklash. The concept is used in large robots at a Volkswagen factory in Germany, for administration of radiation therapy where the irradiation head must rotate reliably at a very low speed, and in follower controls for heliostat energy plants and microscopic parts production.

Several very large assembly systems with laser locator and calibration technology were on partial display. A few had 2-D video inspection sensors which compared an image of a moving product with a stored reference image. One demonstration of this type inspected cigarette packages at the rate of about a hundred per minute, and claimed a "practical"(less than 5%) false reject rate. On casual inspection, it was difficult to know just what the system was looking for. Perhaps a good rectangular outline with no hanging bits of paper or wrapping constituted an acceptable image. Once again, however, the materials handling and simple sensor end of the business seemed to be proceeding without much use of really complex discrimination and control. As in most of the rest of the exhibition, nearly everything was debugged, was running smoothly, and was now available off the shelf, but usually it was not all <u>that</u> advanced; any engineer could see generally how it was done.

Very few hardware exhibits from American or other nations were on display, so it was hard to estimate which countries are "ahead" right now in the kind of robot technology presented at exhibitions like this. Many observers, including the writer, would bet that Japan is either Number 1 or Number 2 in many of the <u>practical</u> robot areas and is coming up fast in traditionally strong Western domains such as modeling and software.

During the month of the robotics conference, three applications received publicity throughout the Orient. Waseda University showed off its "piano playing" robot on TV. The setup played a few tunes well enough, though one musician observed that it "...needs a lot of work on trills and expression." In some ways the system is quite an advance over the mechanical piano players of the past; a "finger" can, for instance, strike a key 10 times a second, faster than any human; and there is a cross-fingering capability wherein the thumb on a hand can go under an index or middle finger. An amusing possibility is for such systems to execute "concertos" which no human could perform. Extension to other instruments is already underway at some of the Japanese keyboard manufacturers.

Bunraku theatre puppet shows are a traditional entertainment in Japan and the puppeteers are respected artists. A project has recently "robotized" the Umegawa character via 29 servo motors and a bank of five microcomputers. (In the public performance, the opposite Chubei character was controlled by three human puppeteers; newspaper critics were generally laudatory.)

The Okochi Memorial Prizes are given annually to workers in all fields of Japanese

science and technology. The awards are among the highest honors in the country. (Professor Masatoshi Okochi, 1878-1952, was a leading scientific educator.) Among the 1982 winners was the Niigata Converter Company project on their Nighttime Unmanned Machining System. The pressures for undertaking the system were primarily economic: there was a competitive cost reduction necessity for relatively short runs of automotive gear products and management anticipated an increase in total production. Location of the Niigata factory in the far North, where heavy snows cause manning problems during the winter months, was also a consideration. Feasibility and planning studies were encouraging and within a couple of years the main parts of a prototype unmanned work station were operating. Niigata Converter, and its neighboring company Niigata Engineering, designed some of the important components themselves and have several Japanese patents on the technology.

Net gains were spectacular: manhours were reduced by more than 70% on some product runs, system operating hours were essentially doubled, productivity was up by nearly an order of a magnitude. These successes led to steady expansion of the original unmanned station ideas and there are now mill, boring and lathe operations running every night. By 1982, night-operating unmanned equipment stations in the Niigata factory were producing some 30% of the plant's output. Judging from published photos, these systems definitely are not pretty. One lathe robot area, for instance, is dominated by a large work feeder full of parts pallets. At Niigata, one sees no sweeping control arms painted in pastel colors, no air conditioned control booths full of antiseptic computer terminals. Perhaps the beauty of the systems should be sought in their productivity figures, and in the fact that 10 hours of totally unmanned operation is typical (average of three failures or partial failures per month; usually, graceful degradation is designed into the system and there have been no catastrophes). With capabilities like those, the company will have plenty of opportunities to dress up the unmanned work stations and the manned ones too!

The Niigata case illustrates some of the real strengths of Japanese industrial robotics: a willingness to undertake the incremental engineering required, great patience in assembling the technology from different sources into a practical system without waiting for some "ultimate" configuration, and the skillful introduction of a trial setup into existing production facilities. On this last issue, Niigata was careful to involve as many shops and employees as possible with the new system. The company emphasized that the unmanned capability, if successful, would have positive impacts on all employees, and guaranteed that nobody would be laid off because of it. Also, employees were asked to "set goals" for the new system and to monitor its development. Goal setting strategies, which are among the most reliable techniques for motivating and getting people interested in something, were thus introduced in an intriguing way. Reportedly, many employees became caught up in the new system's success and were "rooting" for it to meet its goals.

CONCLUDING REMARKS

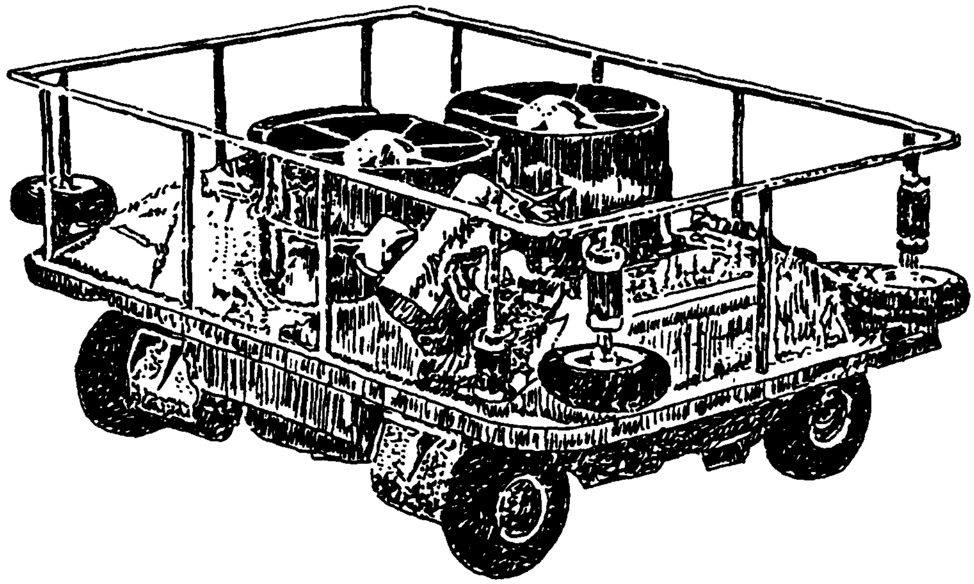
Walking through the Robotics Exhibition and hearing the conference papers, it was easy to feel both disappointed and exhilarated. The disappointment comes from the large number of rather pedestrian applications so far (another spot welder?) and the exhilaration from the prospects. Take the "hand" or manipulator domain. With all the good people, bright ideas, and trial systems about in America, Japan, France, and other countries, we know that some good things are due to emerge, and that these will most likely come from those places which have stayed closest to basic research in manipulator processes. Certain areas are clearly drawing closer together. Sensor-based sequences of

actions such as welding and machining are getting more flexible, and are gradually moving away from the prevailing fixed sequence machines. That movement should dovetail neatly with another trend: more emphasis on model-based (hence programmable and flexible) decisions as to what a system should do next.

Special vehicle developments will probably continue to be rather gradual, as this part of the robotics field seems to take years to produce vehicles just marginally better than the present generation. It takes a long time for various vehicular concepts to be assimilated across laboratories and nobody seems to be making money on vehicles. One also hears of excessive claims and a few disappointments so that industrial managers are apt to choose conservative conveyors or track-mounted systems rather than to invest in radically new vehicles.

The vision processor and scene analysis area may be one of the best places to look for real advances in the next few years. The laboratory technology is already far beyond a simple 2-D image comparator approach such as was demonstrated in the cigarette pack inspector. Projects at Carnegie-Mellon University and elsewhere are now able to construct 3-D perspective pictures of some real objects from several 2-D images of those objects. To accomplish such transformations, the relations between "surface," "idealized object," and "scene" levels of interpretation must be precisely defined, and this already can be done for a range of fairly regular objects. The computational requirements for this kind of analysis are severe, and if one tries to imagine a whole "flexible factory" full of such scene analyzers the prospect seems distant indeed. But computational barriers have a way of receding with the years. Even a few successful industrial applications of really complex scene analysis could move us a lot closer to that tantalizing robotized world which is always just over the horizon.

Top view



Bottom view

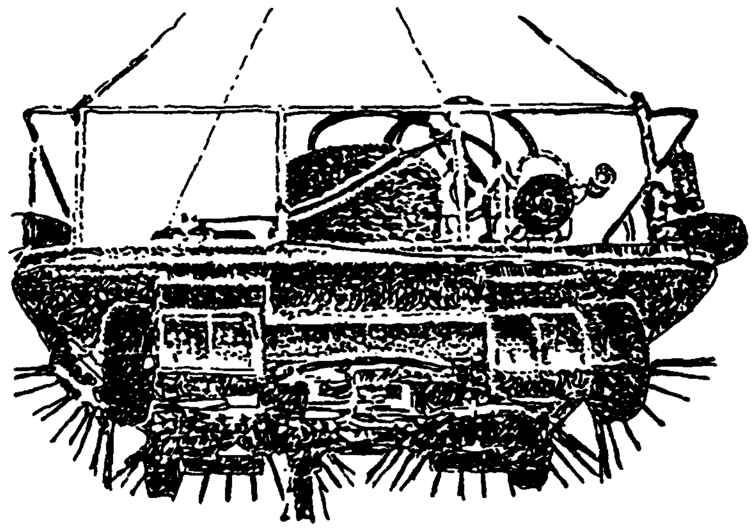


Figure 1. The Mitsubishi Cleaner Vehicle

* All figures and tables are taken from the *Proceedings of the '83 ICAR, International Conference on Advanced Robotics, Tokyo, Japan,* 1983 (Japan Industrial Robot Association, 1983)

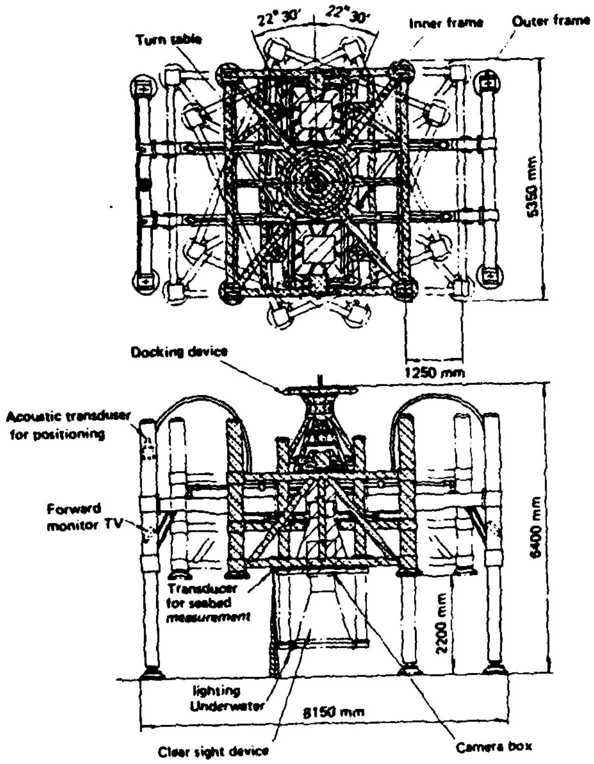


Figure 2. ReCUS Body Section

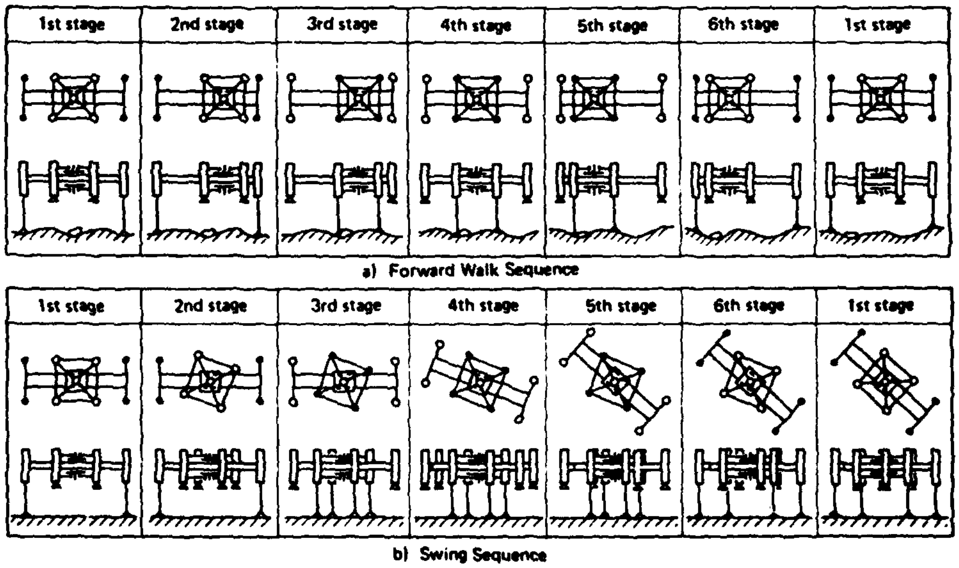


Figure 3. ReCUS Walking Sequence

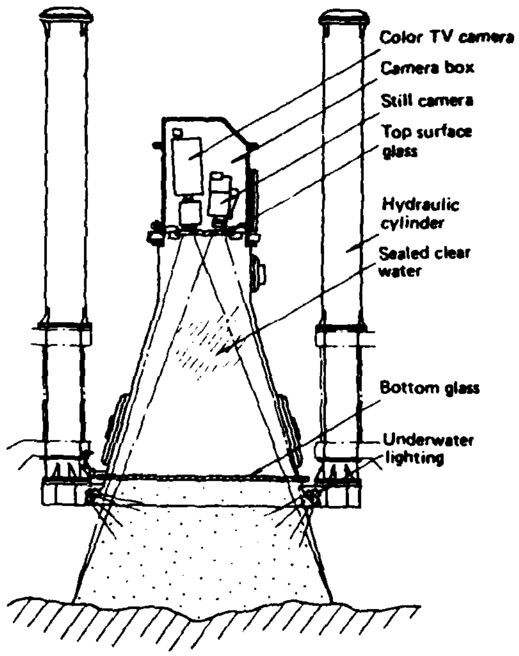


Figure 4. ReCUS Clear Sight Device

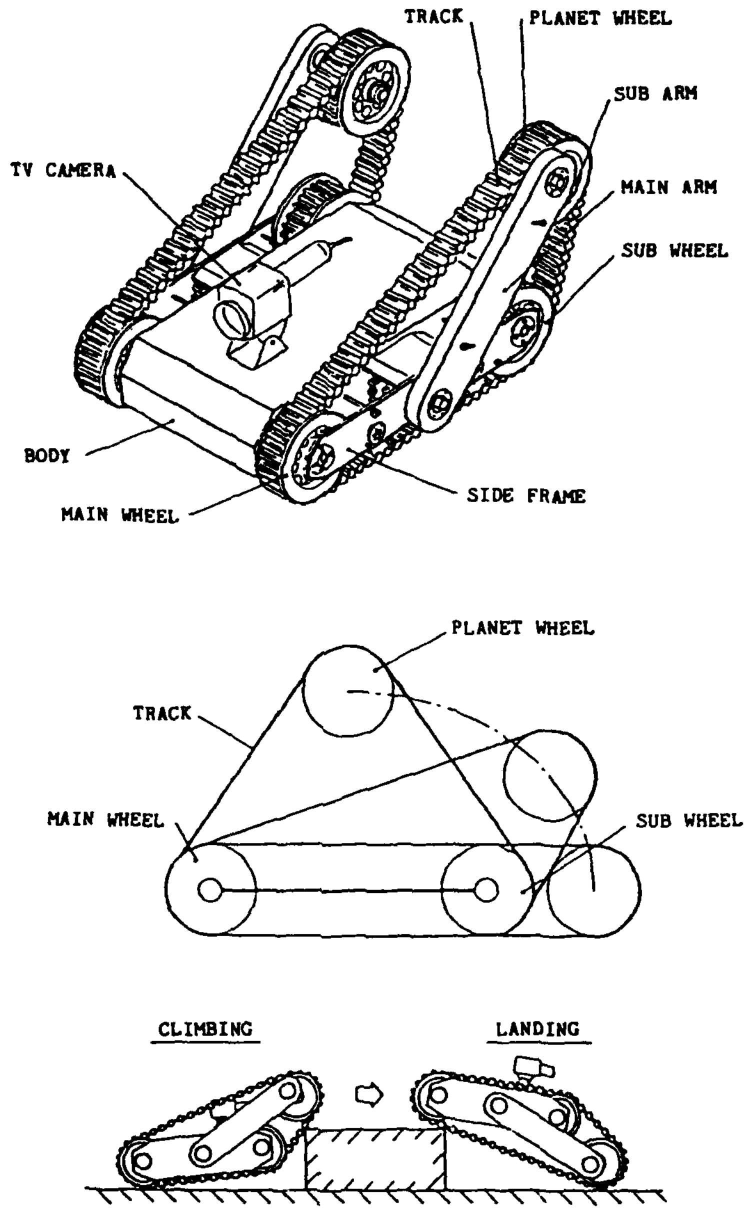
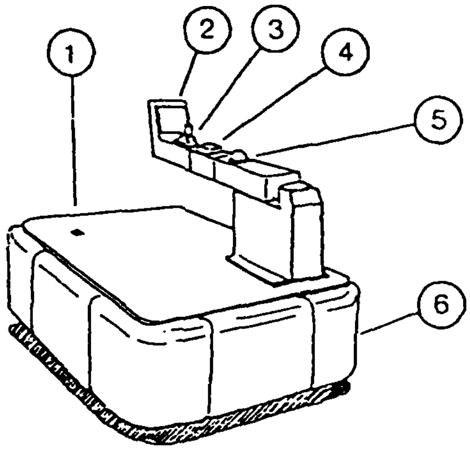


Figure 5. Hitachi Transformable Crawler Vehicle



1. Main Power Switch
2. Electroluminescent display
3. Joy-stick
4. Ten-key imput device
5. Track ball
6. Bumper sensor

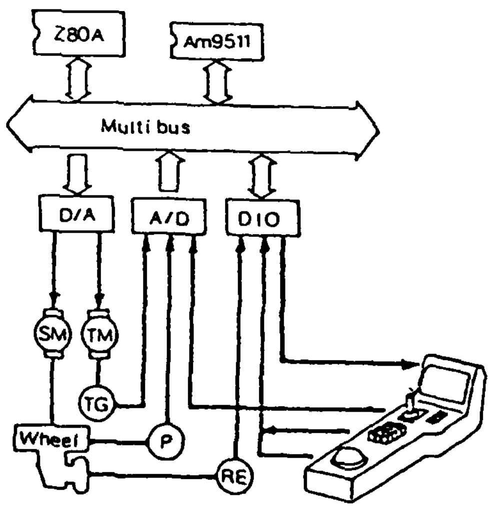


Figure 6. MITI ODV-2 Melchair Configuration and Control System

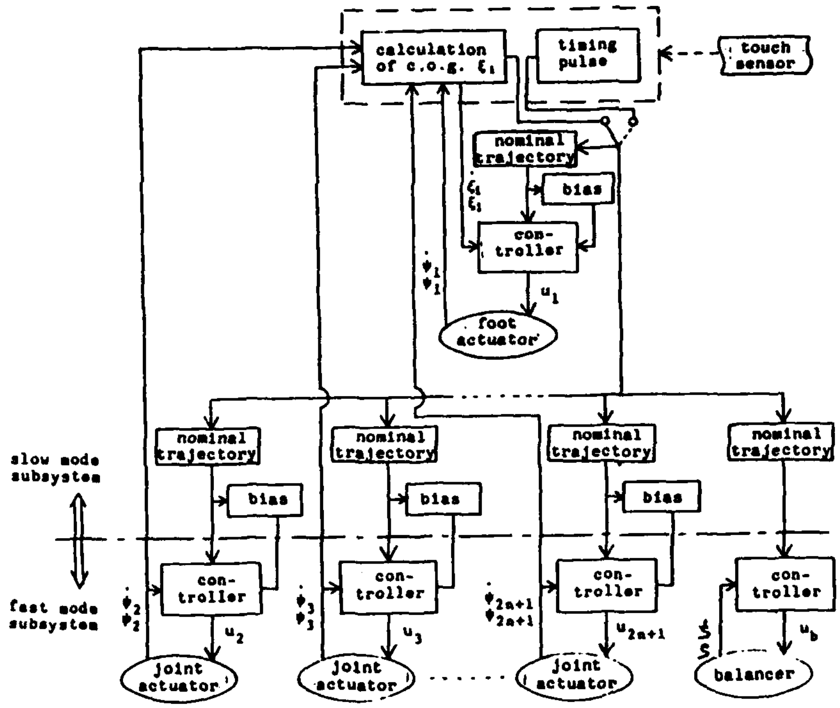


Figure 7. Control System for Osaka Biped Robot

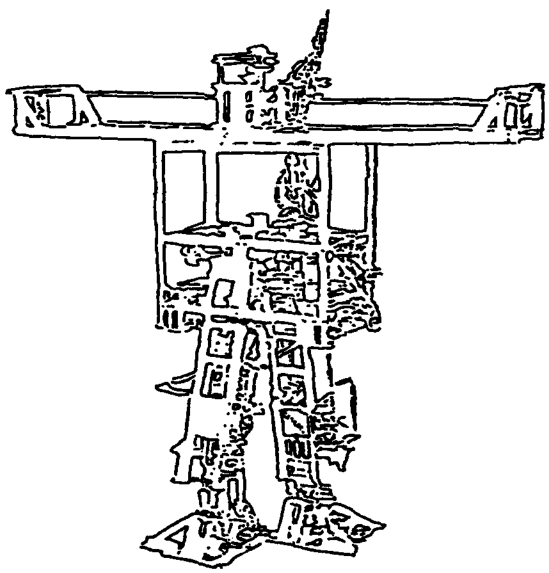


Figure 8. Present Prototype of Osaka Biped Robot

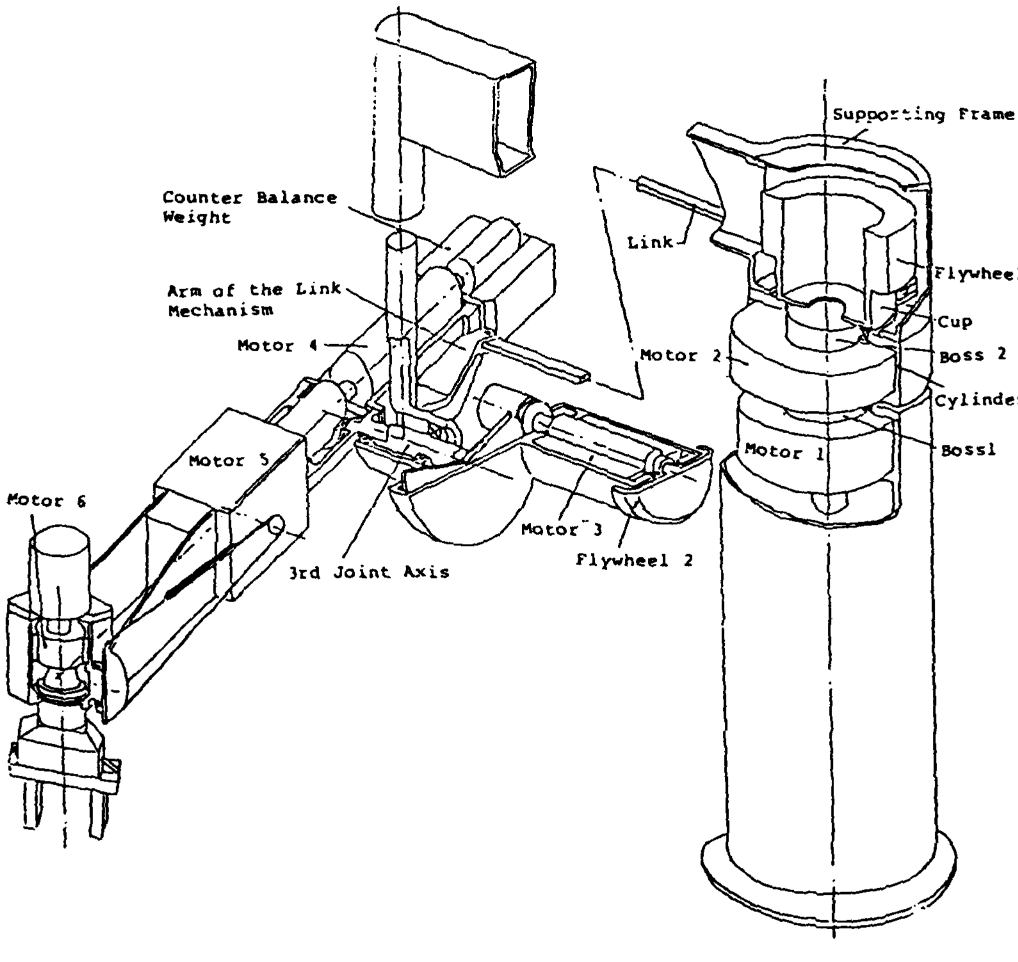


Figure 9. Structure of Electrotechnical Laboratory ETA-2 Vehicle

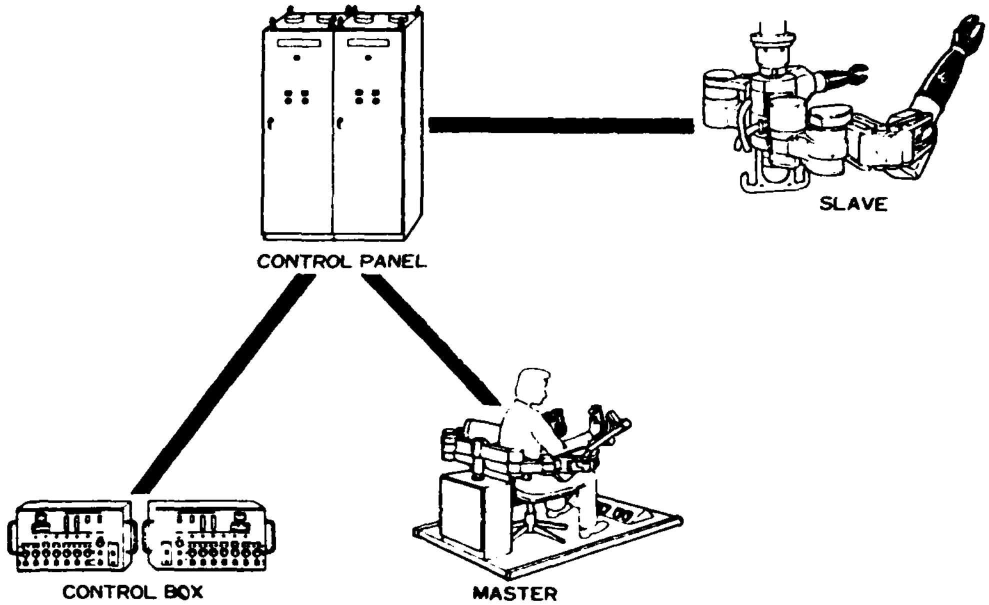


Figure 10. General View of PNC "Ingenious Wrist" Manipulator

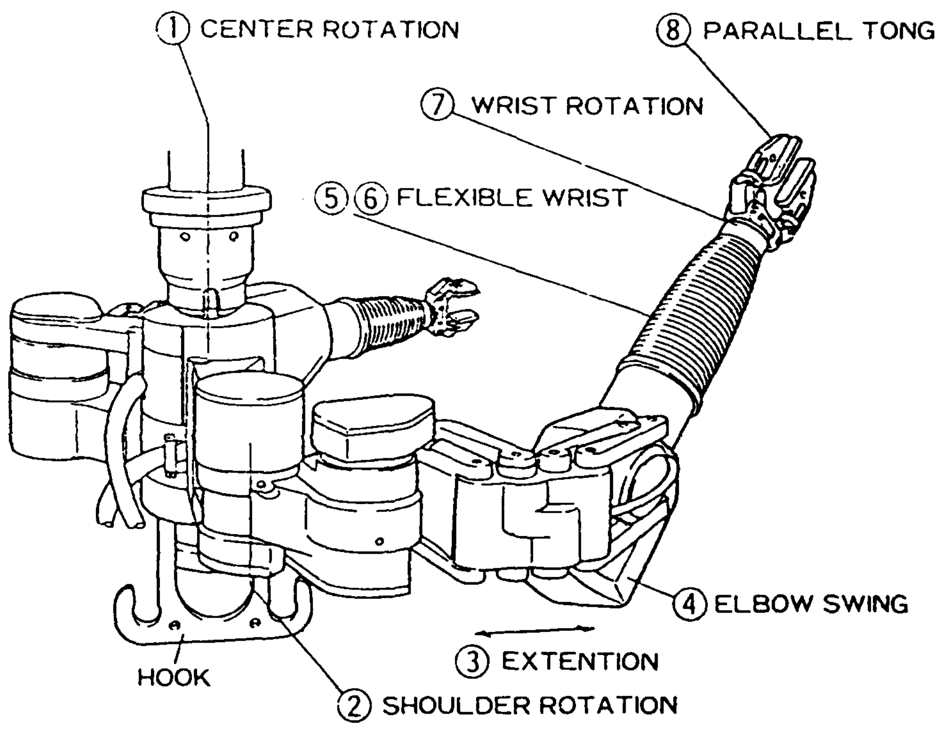
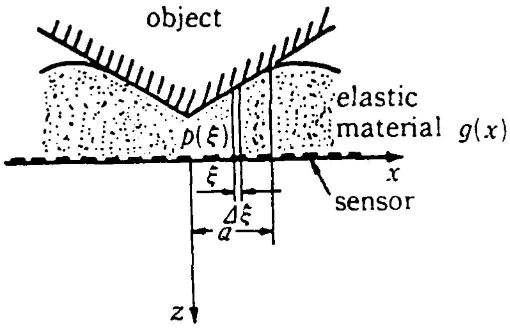
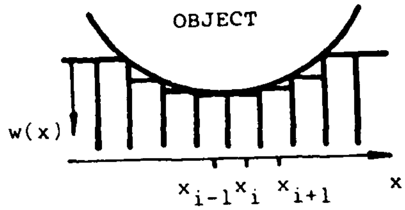


Figure 11. Close-up View of PNC "Ingenious Wrist" Slave Unit



A model of the tactile sensor



A discrete model of the tactile sensor

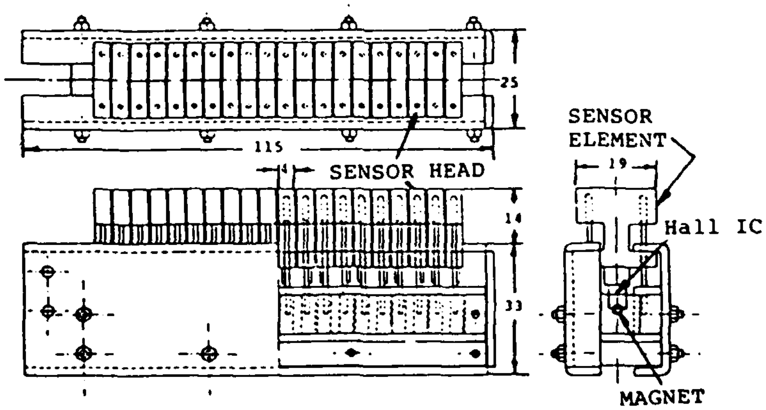


Figure 12. The Chuo Tactile Sensor

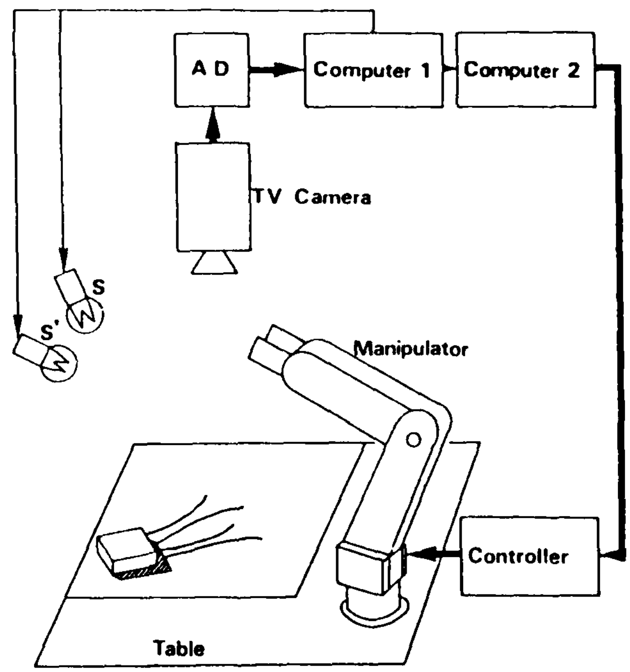
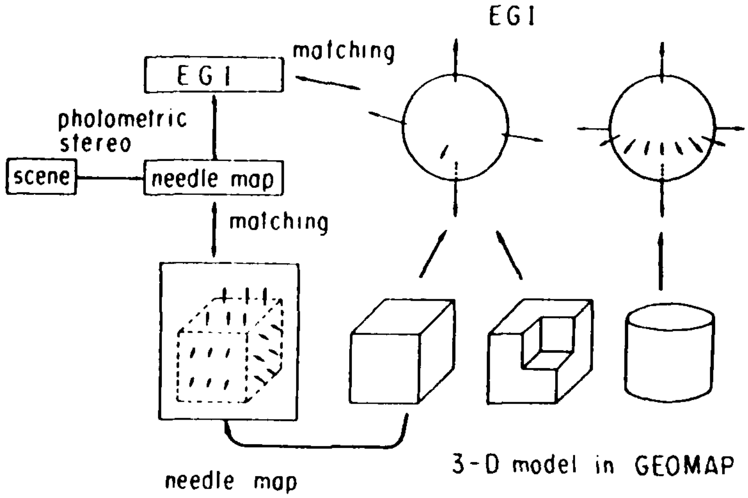


Figure 13. Setup for Osaka WIRESIGHT System



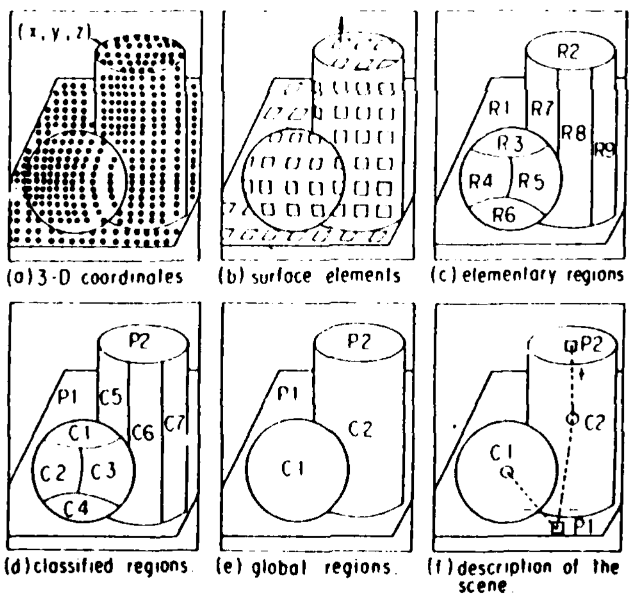


Figure 14. The Electrotechnical Laboratory Vision Recognition System: EGI and Region Analysis

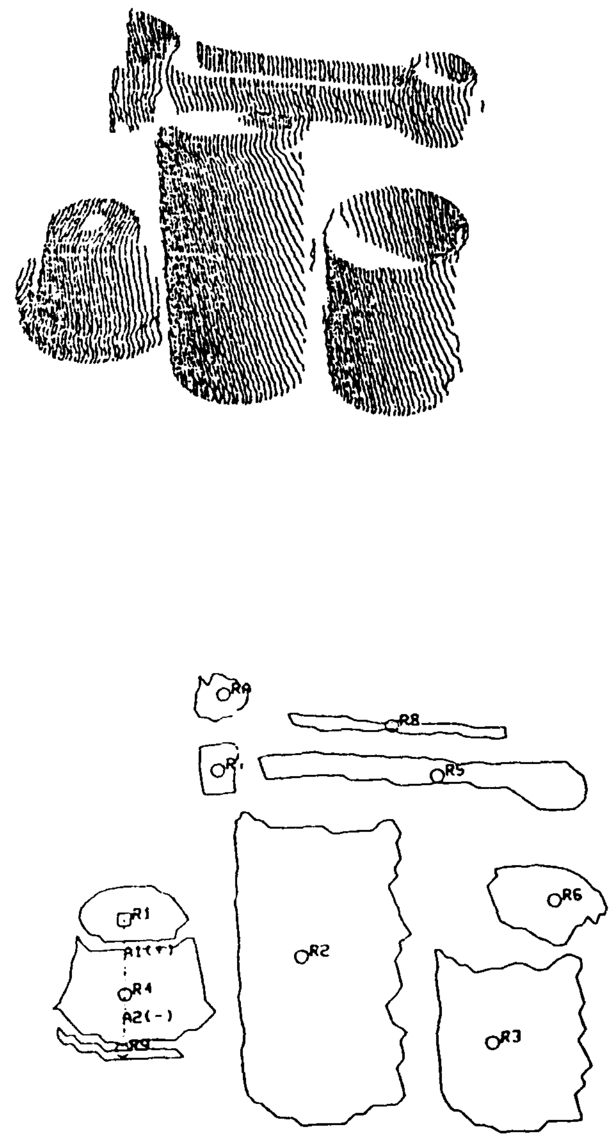


Figure 15. The Electrotechnical Laboratory Vision Recognition System: Stripe Image and Regional Description of a Scene

TABLE I

FUTURE PROSPECTS OF JAPANESE ROBOT TECHNOLOGY

Years of Actualization	Issue	Degree of Importance(%)
1992	Diffusion of low-cost, general-purpose robots, capable of performing most simple tasks, by changing control modules.	34
	Full use of robots in dangerous sites and environments where work tasks involving poisonous gas, radioactivity, excessive dust, etc. will increase.	86
1993	The application of intelligent robots to work in place of man in special environments such as aerospace, undersea, and inside nuclear reactors will be achieved.	81
	Various types of undersea robots performing observation, inspection, and tasks at a depth of hundreds of meters will be in common use.	52
1994	Rationalization and safety of construction works will be greatly enhanced by the introduction of large-size construction machines and intelligent robots to the civil construction work sites which will perform tunnel excavation, and underwater tasks or works at high locations.	79
1995	Robots capable of processing 100 frames of image, (with the number of picture elements of each frame at approximately 1,000 x 1,000) per second will be developed.	30
1996	Technology to produce mining robots to realize unmanned mining activities will be developed.	50
1997	At homes and hospitals, service robots performing miscellaneous tasks will be in use.	20
1998	Intelligent robots will be introduced to construction work sites.	23
	Robot systems will be in operation at fish culture and man-made fish farms to conduct management and harvesting works.	8

TABLE II

FUNCTIONAL AND INSTITUTIONAL UNITS IN BRITISH INDUSTRIAL ROBOTICS

1. Dynamics and Control

   Edinburgh; QMC; Liverpool Poly; Newcastle; Surrey/GEC Robot Systems; Cambridge/CEI.

2. Robot Design/Hardware

   Loughborough/Martonair; UCL; Surrey; Gwent; Open University; Cranfield/Remek; USIST/British Robotic Systems; Birmingham/Unimation; Cranfield/Thorn-EMI.

3 Image Handling

   QMC/Micro Consultants; Edinburgh/GEC Hirst; Royal Holloway College/ United Biscuits, Unilever; RAL/Computer Recognition Systems.

4. Arc Welding

   Loughborough/British Rail; Newcastle/Austin Pickersgill; Oxford/BL Technology, Fairey Automation, GEC Electrical Projects; Cranfield/BLT; UMIST; Liverpool/Welding Institute.

5. FMS including Assembly

   4.1 Offline Programming Environment: Cranfield, Edinburgh/Robot Language Working Party; Leicester Poly/RLWP; Nottingham/PERA; Cambridge.
   4.2 Sensors:
   Vision: Cranfield/Remek, Hull/GEC Marconi
   Tactile: Sussex/EMI; QMC
   Ultrasonic: Nottingham/Transtec
   4.3 Flexible Assembly including Product Redesign: Cranfield/Tube Investments; Salford/Fairey Automation; Hatfield Polytechnic/Delco Products; Bath/Westlands, Normalair Garrett.
   4.4 Error Recovery, Reliability: Aberystwyth/British Robotic Systems; Imperial College.
   4.5 Cost/Cycle Time Comparisons: Imperial College.
   4.6 Systems Studies: Loughborough/Partner to be confirmed.

6. Grinding and Polishing: Bath/Walker Crossweller.

7. Unmanned Industrial Trucks: Warwick/Lansing Bagnall.

8. Textiles: Hull/Corah; Loughborough/Partner to be confirmed; Durham/Lyle and Scott.

9. Composites: Queens University, Belfast/Short Brothers

10. Robotic Inspection and Calibration: Lanchester Polytechnic; Survey; Loughborough LK Tools; Portsmouth Polytechnic/Turnwright Controls.

11. Meat Processing: Imperial College/Glengrove.

TABLE III

ANTIFOULING TECHNOLOGIES FOR SEA WATER COOLING SYSTEMS: THE MITSUBISHI ANALYSIS

TABLE-1 POSSIBLE ANTI-FOULING PROCESSES FOR POWER STATION SEA WATER SYSTEM

PRINCIPLE	PROCESS	DESCRIPTION	PROBLEMS	REMARKS
1. Chemical Inhibition	1 Chlorine/Hypochlorite Dosing	Most widely applied with stable effect, concentraion 2 ~ (10) ppm	To be reduced in ecological view (in the future)	
	2 Anti-Fouling Paint Coating	Paint containing cuprous oxide and/or organic tin is usually applied	To be reduce [illegible] ecological view (Re-coating at several years interval required)	
	3 Copper Alloy Lining	Used for ship hull anti-fouling, but not common for channel application	To be reduced in ecological view	Macfree'n (MHI)
	4 Ozonation	Injection of ozon solution. Reported to be effective for slime fouling	Availability of large capacity ozonizer	
2. Physical Inhibition	1 Sonic/Ultrasonic Excitation	Reported to be effective for specific spectrum and phase of growth	Low efficiency, high investment/operating cost	
	2 Ultraviolet Irradiation	- Ditto -	- Ditto -	
	3 Electro-Magnetic Field Treatment	Impression of strong magnetic field Mechanism of inhibition is not clear.	Questionable in large scale application	Hydro Dynamics Corp. U.S.A.
	4 Hot Water Recirculation	Heating over 45°C, holding more than several hours are required	High operating cost Disposal of hot water	
	5 Increase of Velocity	Effective for pipeline anti-fouling Velocity over ~ 3.5 m/s	Increase of horsepower Not applicable to channel	
3. Mechanical Removal	1 High Speed Water Jet	Jet nozzle sweep/traverse be required	Low efficiency in case of underwater jet	
	2 Rotary Brush/Scraper	Primitive method but most stable effect is expected.	Life and effect of remover Applicability to coated surface	Joint Research between TEPCO-MHI
	3 Shock Wave Excition	Underwater electrical discharge or explosion	Not practical at large scale Operating safety	
	4 Use of Pig or Baloon	Actually applied for condenser tube cleaning.	Limited application to actual channel/pipeline system	

TABLE IV

ROBOTS FOR FIRE FIGHTING AND PREVENTION

Purpose	kinds	features
inspection	① inspection robot (including single function inspection robot)	Portable type belonged to fire department. Remotely controllable. Searching remainders / measurement of fire environment.
refuge guidance	② refuge guidance robot	Portable type belonged to fire department. Remotely controllable. Oxygen mask. Carring of protector for refuge and survival capsule. Refuge guidance.
	③ standing refuge guidance robot	Standing robot equipment on each floor of hotel etc.. Detection of firing spot, and alarm for refuge of guidance. Supply of protector for refuge. Guide wire method.
rescue	④ capsule robot	Guiding remainder into survival capsule, and chasing refuge guidance robot.
	⑤ manned rescue vehicle	Rescue of non walkable persons / faint persons. Manned operation.

INTERNATIONAL MEETINGS AND EXHIBITIONS IN THE FAR EAST

1984-1986

Compiled by Seikoh Sakiyama

The Australian Academy of Science, the Japan Convention Bureau, and the Science Council of Japan are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1984

Date	Title	Site	For information, contact
January 25-28	Internepcon Semiconductor/Japan '84 (International Electronic Production Conference)	Tokyo, Japan	Cahners Exposition Group S.A., Japan Hino Building 3-4-11, Uchi-Kanda Chiyoda-ku, Tokyo 101
February 12-16	The 14th Australian Polymer Symposium	Ballarat, Australia	Dr. G.B. Guise P.O. Box 224 Belmont, Victoria 3216
February 16-18	Electrooptics/Laser International Japan '84	Tokyo, Japan	Cahners Exposition Group S.A., Japan Hino Building 3-4-11, Uchi-Kanda Chiyoda-ku, Tokyo 101
February 21-24	'84 Mechatronics Japan Exhibition	Tokyo, Japan	Nihon Keizai Shimbun Company, Ltd. 1-8-5, Ohtemachi Chiyoda-ku, Tokyo 100
February 22-24	'84 Office Automation Show	Tokyo, Japan	Nippon Administrative Management Association Osaka Head Office Osaka Science Museum 1-8-4, Utsubo-Hommachi Nishi-ku, Osaka 550
February (tentative)	International Conference on Mesoscale Meteorology	Australia, (undecided)	Royal Meteorological Society Australian Branch P.O. Box 654 Melbourne, Victoria 3001
February (tentative)	The 8th Industrial Robot Film Festival	Tokyo, Japan	Japan Industrial Robot Association 3-5-8, Shiba-Koen Minato-ku, Tokyo 105

Date	Title	Site	For information, contact
March (tentative)	Geology, Mineral and Energy Resources of Southeast Asia	Kuala Lumpur, Malaysia	Dr. T.T. Khoo Department of Geology University of Malaya Kuala Lumpur 22-11
April 3-5	International Teleconference Symposium	Tokyo, Japan	Data Communications Department Kokusai Denshin Denwa Company, Ltd. 2-3-2, Nishi-Shinjuku Shinjuku-ku, Tokyo 160
April 3-6	Communications Tokyo '84 (Exhibition)	Tokyo, Japan	Communication Industries Association of Japan Sankei Building Annex, 8F 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
April 10-13	Softopia '84 Tokyo (Computer Software)	Tokyo, Japan	Softopia '84 Tokyo Secretariat SK Building 1-22-9 Ginza Chuo-ku, Tokyo 104
April 20-21	OA Show [Office Automation (OA)]	Osaka, Japan	Nihon Keizai Shimbun Company, Ltd. 1-1, Maenocho, Kyobashi Higashi-ku, Osaka 540
April 24-27	Computer Graphics Tokyo'84 (International Conference and Exhibition)	Tokyo, Japan	Japan Management Association 3-1-22 Shiba-Koen Minato-ku, Tokyo 105
May 9-13	'84 Tokyo International Metalworking Machines Exhibition '84 Tokyo Metalforming Machines Exhibition '84 Yamagata Machinery Industry Exhibition '84 Industrial Robots Exhibition	Tokyo, Japan	The Industrial Daily News 1-8-10, Kudan-Kita Chiyoda-ku, Tokyo 102

Date	Title	Site	For information, contact
May 15-18	The 11th Modern Scientific Instruments Exhibition	Nagoya, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
May 25-27	The 14th Hamamatsu Environment Preserving Machinery and Equipment Exhibition	Hamamatsu, Japan	The Nihon Kogyo Shimbun Company, Ltd. 2-4-9, Umeda Kita-ku, Osaka 530
May (tentative)	The 5th International Soils Expansion Conference	Adelaide, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
May (tentative)	The 21st All Japan Optical Measuring Instruments Fair	Tokyo, Japan	Japan Optical Measuring Instruments Manufacturers Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
May (tentative)	Microcomputer Show '84	Tokyo, Japan	Japan Electronic Industry Industry Development Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
June 11-13	The 4th Congress on World Computing Services Industry	Tokyo, Japan	Japan Software Industry Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
June 11-14	'84 CAD/CAM System Show	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
June 13-16	The 14th JPCA Show '84 [Japan Printed Circuit Association (JPCA)]	Tokyo, Japan	Japan Printed Circuit Association Kamiyacho Building, 6F 5-12-12, Toranomon Minato-ku, Tokyo 105

1984 Continued

Date	Title	Site	For information, contact
June (tentative)	'84 Tokyo International Antipollution Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
June (tentative)	New Matex '84 (New Materials and Related Equipment and Systems) Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
July 11-14	The 4th International Drying Symposium	Kyoto, Japan	Dr. Ryozo Toei The Society of Chemical Engineers, Japan 4-6-19, Kobinata Bunkyo-ku, Tokyo 112
July 22-August 1	International Symposium on Marine Plankton	Shimizu, Japan	Mr. T. Kubota Marine Biological Center Tokai University 1000, Orito, Shimizu Shizuoka 424
July 25-27	Hi-Tech '84 Osaka Exhibition	Osaka, Japan	Secretariat, Hi-Tech '83 c/o Marcom International, Inc. Akasaka-Omotemachi Building, Rm 705 4-8-19, Akasaka Minato-ku, Tokyo 107 (Application necessary)
July 25-28	The 10th International Symposium on Nonlinear Acoustics	Kobe, Japan	Dr. Akira Nakamura, Chairman, The Institute of Scientific and Industrial Research Osaka University 8-1, Mihogaoka, Ibaraki Osaka 567
July 26-30	The 10th International Congress of Biometeorology	Tokyo, Japan	Dr. Hiroshi Inaba Juntendo Medical School 2-1-1, Hongo Bunkyo-ku, Tokyo 113

1984 Continued

Date	Title	Site	For information, contact
July (tentative)	'84 Microcomputer Show	Osaka, Japan	Japan Electronic Industry Development Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
August 19-24	The 13th Congress of the International Commission for Optics	Sapporo, Japan	Professor S. Fujiwara Secretary of the ICO-13, Sapporo c/o Simul International Inc., Kowa Building 1-8-10, Akasaka Minato-ku, Tokyo 107
August 24-30	The 5th International Congress on Mathematical Education	Adelaide, Australia	Dr. John Mack Department of Mathematics University of Sydney N.S.W. 2006
August 26-31	The 3rd International Congress on Cell Biology	Kyoto or Kobe, Japan	Japan Society for Cell Biology Shigei Medical Research Institute 2117, Yamada Okayama 701-02
August 26-September 1	International Conference on the Photochemical Conversion and Storage of Solar Energy	Osaka, Japan	The Society of Kinki Chemical Industry 1-8-4, Utsubo-Hommachi Nishi-ku, Osaka 550
August 27-31	Shiga Conference '84 on Conservation Management of World Lake Environment	Otsu, Japan	Department of Civil Life and Environment Shiga Prefectural Government 4-1-1, Kyomachi, Otsu Shiga 550
August 27-September 1	The 9th International Conference on Raman Spectroscopy	Tokyo, Japan	Professor M. Tasumi Department of Chemistry Faculty of Science Tokyo University 7-3-1, Hongo Bunkyo-ku, Tokyo 113

1984 Continued

Date	Title	Site	For information, contact
August (tentative)	'84 Home Mechatronics Show	Osaka, Japan	'84 Home Mechatronics Show Office Nihon Keizai Shimbun Company, Ltd. 1-1, Maenocho, Kyobashi Higashi-ku, Osaka 540
September 1-7	The 6th International Congress of Virology	Sendai, Japan	Professor T. Ebina Department of Bacteriology, Medical School Tohoku University 2-1, Seiryo-cho Sendai, Miyagi 980
September 2-7	International Symposium on Snow and Ice Processes at the Earth's Surface	Sapporo, Japan	The Institute of Low Temperature Science Hokkaido University 8-chome, Kita 19-Jyo Kita-ku, Sapporo 060
September 2-8	The XIIth International Biometric Conference	Tokyo, Japan	Dr. T. Okuno Department of Mathematical Engineering and Instrumentation Physics Faculty of Engineering Tokyo University 7-3-1, Hongo Bunkyo-ku, Tokyo 113
September 3-7	The 1st International Conference on Technology of Plasticity	Tokyo, Japan	Japan Society for Technology Plasticity Torikatsu Building, 3F 5-2-5, Roppongi Minato-ku, Tokyo 106
September 3-7	The 9th International Symposium on Nerosecretion	Fuji, Japan	Professor S. Ishii Department of Biology School of Education Waseda University Nishi-Waseda Shinjuku-ku, Tokyo 160
September 10-15	The VII International Symposium on Organosilicon Chemistry	Kyoto, Japan	Dr. Makoto Kumata Faculty of Engineering Kyoto University Yoshida-Honcho Sakyo-ku, Kyoto 606

1984 Continued

Date	Title	Site	For information, contact
September 11-14	The 10th International Conference of IMEKO TC-3 on Measurement of Force and Mass (International Measurement Confederation)	Kobe, Japan	Professor T. Ono Department of Mechanical Engineering College of Technology University of Osaka 4-804, Ume-machi, Mozu Sakai, Osaka 591
September 19-22	IATSS Symposium on Traffic Science 1984	Tokyo, Japan	International Association of Traffic and Safety Sciences 2-6-20, Yaesu Chuo-ku, Tokyo 104
September 25-29	'84 Tokyo Industrial and Engineering Exhibition '84 Tokyo Engineering Design Efficiency Exhibition '84 Tokyo Automatic Control and Instrumentation Exhibition '84 Tokyo Automatic and Labor-Saving Machines Exhibition '84 Computer Graphic System Show	Tokyo, Japan	The Industrial Daily News 1-8-10, Kudan-Kita Chiyoda-ku, Tokyo 102
September (tentative)	NRDO Conference 1984 (National Research Development Organization	Kyoto, Japan	Research Development Cooperation of Japan 2-5-2, Nagata-cho Chiyoda-ku, Tokyo 100
September (tentative)	'84 Fluid Power International Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
October 1-6	The 3rd Asian Pacific Regional Astronomy Meeting of IAU	Tokyo, Japan	Professor T. Kogure Department of Astronomy, Faculty of Science University of Kyoto Sakyo-ku, Kyoto 606

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Date	Title	Site	For information, contact
October 1-7	Pacific Region Wood Anatomy Conference	Tsukuba, Japan	P.O. Box 16 Tsukuba Agricultural and Forestry Research Institute Ibaraki 305
October 3-6	The 11th Measuring Instruments Exhibition	Tokyo, Japan	Japan Measuring Instruments Federation 25-1, Nandocho Shinjuku-ku, Tokyo 162
October 4-9	'84 Japan Electronics Show	Tokyo, Japan	Japan Electronics Show Association c/o Tokyo Chamber of Commerce and Industry 3-2-2, Marunouchi Chiyoda-ku, Tokyo 100
October 7-12	The XVIIth International Congress of Internal Medicine	Kyoto, Japan	The Japan Society of Internal Medicine Hongo Daiichi Building, 8F 3-34-3, Hongo Bunkyo-ku, Tokyo 113
October 16-18	1984 International Symposium on Electromagnetic Compatibility (EMC)	Tokyo, Japan	Professor T. Takagi Department of Electrical Communications Faculty of Engineering Tohoku University Sendai, Miyagi 980
October 22-26	The 9th International Conference on Infrared and Millimeter Waves	Takarazuka, Japan	Dr. H. Yoshinaga Department of Applied Physics Osaka University Yamadaoka, Suita Osaka 565
October 30-November 8	The 12th Japan International Machine Tool Fair	Tokyo, Japan	Osaka International Trade Fair Commission c/o International Hotel 58, Hashizume-cho Uchi-Hommachi Higashi-ku, Osaka 540

Date	Title	Site	For information, contact
October 30 November 2	The 7th International Conference on Computer Communication (ICCC'84)	Sydney, Australia	Dr. R. Cook Overseas Telecommunications 32-36 Marine Place Sydney, N.S.W. 2000
October (tentative)	The 12th NECA Technical Fair	Tokyo, Japan	Nihon Electric Control Equipment Industry Association Daimon Hikari Building 2-1-18, Hamamatsucho Minato-ku, Tokyo 150
October (tentative)	Software Show '84	Tokyo, Japan	Japan Software Industry Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
October (tentative)	1984 Japan Machinery Fair	Nagoya, Japan	Nagoya-shi Mihon-ichi Kyokai 2-6-3, Fukiage Chikusaku, Nagoya 464
October (tentative)	Data Show '84	Tokyo, Japan	Japan Electronic Industry Development Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
October (tentative)	'84 Vacuum General Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
October (tentative)	'84 Osaka International Environment Preserving Machinery and Equipment Exhibition '84 Resources Recycling Technology and Energy Saving Instrument Exhibition	Osaka, Japan	The Nihon Kogyo Shimbun Company, Ltd. 2-4-9, Umeda Kita-ku, Osaka 530

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Date	Title	Site	For information, contact
	'84 Osaka Physical Distribution and Materials Handling Exhibition		
	'84 Robot and Automation Equipment Fair		
November 12-15	The Second International Conference on Electro-static Precipitation	Kyoto, Japan	Professor Senichi Masuda Chairman, The Institute of Electrostatics Japan Sharumu 80 Building, 4 F 4-1-3, Hongo, Bunkyo-ku Tokyo 113
November 22-23	Technology: Past, Present, and Future	Melbourne, Australia	Executive Officer Australian Academy of Technological Sciences Clunies Ross House 191 Royal Parade Parkville, Victoria 3052
November (tentative)	The 7th International Hospital Engineering Exhibition (Hospex Japan '84)	Tokyo, Japan	Japan Management Association Kyoritsu Building 3-1-22, Shiba-Koen Minato-ku, Tokyo 105
November (tentative)	'84 Japan Education Materials Exhibition	Undecided	Japan Association of Manufacturers and Distributors of Educational Materials 1-17-1, Toranomon Minato-ku, Tokyo 105
November (tentative)	Microsystem Show '84	Tokyo, Japan	Japan Microphotography Association Daini Okochi Building 1-9-15, Kajicho Chiyoda-ku, Tokyo 101
November (tentative)	The 19th Exhibition and Conference of New Electrical Insulating Materials	Tokyo, Japan	Japan Electrical Insulation Materials Association Iwao Building 1-16-2, Toranomon Minato-ku, Tokyo 105

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Date	Title	Site	For information, contact
November (tentative)	The 23rd Analytical Instruments Show	Tokyo, Japan	Japan Analytical Instruments Manufacturers' Association Taimei Building 3-22, Kanda-Ogawa-cho Chiyoda-ku, Tokyo 100
November (tentative)	'84 Optoelectronic Industry and Technology Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
December 3-5	Semicon Japan '84 (Semiconductors)	Tokyo, Japan	Secretariat, Semicon Japan '83 c/o Marcom International, Inc. Akasaka-Omotemachi Building, Rm 705 4-8029, Akasaka Minato-ku, Tokyo 107

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Date	Title	Site	For information, contact
February 11-14	International Symposium on Characterization and Analysis of Polymers	Melbourne, Australia	Polymer 85 Royal Australian Chemical Institute 191 Royal Parade Parkville, Victoria 3052
February (tentative)	The 5th International Congress of Pacific Science Association	Baguio, Philippines	Dr. Paulo Campos National Research Council of the Philippines General Santos Avenue Bicutan, Taguig Metro Manila

Date	Title	Site	For information, contact
March (tentative)	Annual National Conference of the Institution of Engineers, Australia	Melbourne, Australia	LtCol. J.A. McDonald Secretary, Victoria Division Institute of Engineers, Australia National Science Center 191 Royal Parade Parkville, Victoria 3052
May 20-24	The 3rd Conference on Steel Development	Melbourne, Australia	Australian Institute of Steel Construction P.O. Box 434 Milsons Point, N.S.W. 2061
July 14-20	The 6th International Congress for Ultrasound in Medicine and Biology	Sydney, Australia	Dr. R. Jellins P.O. Box R374, Royal Exchange Sydney N.S.W. 2000
August 12-16	The 6th International Meeting on Ferroelectricity	Kobe, Japan	Professor S. Nomura Physical Electronics Faculty of Engineering Tokyo Institute of Technology Meguro-ku, Tokyo 152
August 18-23	The 8th International Conference on Chemical Education	Tokyo, Japan	The Chemical Society of Japan 1-5, Kanda-Susugadai Chiyoda-ku, Tokyo 101
August 19-24	1985 International Symposium on Lepton and Photon Interactions at High Energies	Kyoto, Japan	Research Institute for Fundamental Physics Kyoto University Oiwake-cho, Kitashirakawa Sakyo-ku, Kyoto 606
August 19-30	The 23rd General Assembly of IASPEI (International Association of Seismology and Physics of the Earth's Interior)	Tokyo, Japan	Intergroup Corporation Akasaka Yamakatsu Building 8-5-32, Akasaka Minato-ku, Tokyo 107

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Date	Title	Site	For information, contact
August 26-30	The 6th International Symposium on Polarization Phenomena in Nuclear Physics	Osaka, Japan	Professor M. Kondo Research Center of Nuclear Physics Osaka University Yamadaoka, Suita Osaka, 530
August (tentative)	Coastal Engineering Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	International Association for Hydraulic Resources Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	The 21st Congress for IAHR (International Association for Hydraulic Research)	Melbourne, Australia	Mr. Robin Vickery Institute of Engineers Australia 11 National Circuit Barton, A.C.T. 2600
September 4-11	The 11th International Teletraffic Congress ITC-11	Kyoto, Japan	ITC-11 Committee Musashino Electrical Communication Laboratory 3-9-11, Midorimachi Musashino, Tokyo 180
September 6-10	1985 Annual Conference of the IIC (International Institute of Communications)	Tokyo, Japan	International Relations Department Japan Broadcasting Corporation 2-2-1, Jinnan Shibuya-ku, Tokyo 150
September 10-13	The 3rd International Cell Culture Congress	Sendai, Japan	Professor S. Yamane Research Institute for Tuberculosis and Cancer Tohoku University 4-1, Seiko-cho Sendai, Miyagi 980

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Date	Title	Site	For information, contact
October 15-18	International Rubber Conference	Kyoto, Japan	The Society of Rubber Industry, Japan Tobu Building 1-5-26, Motoakasaka Minato-ku, Tokyo 107

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March 16-21	The 10th International Congress of Prestressed Concrete	New Delhi, India	Mr. C. R. Alimchandani Stup Consultants, Ltd. 1004-5-7, Raheja Chambers 213 Nariman Point Bombay 420-021
May 11-17	Congress of the International Society of Haematology and the International Society of Blood Transfusions	Sydney, Australia	Dr. I. Cooper, President Haematology Society of Australia Cancer Institute 481 Little Londsdale Street Melbourne, Victoria 3001
July (tentative)	International Institute of Welding Annnual Assembly 1986	Tokyo, Japan	Japan Welding Society 1-11, Kanda-Sakumacho Chiyoda-ku, Tokyo 101
August 25-29	The 12th International Congress of the International Association of Sedimentologists	Canberra, Australia	Professor K.A.W. Crook Department of Geology Australian National University P.O. Box 4 Canberra, A.C.T. 2600
August (tentative)	The 7th World Congress on Air Quality	Sydney, Australia	Mr. K. Sullivan Clean Air Society of Australia and New Zealand P.O. Box 191 Eastwood, N.S.W.
September 21-25	The World Congress of Chemical Engineering	Tokyo, Japan	The Society of Chemical Engineers, Japan Kyoritsu Kaikan 4-6-19, Honhinata Bunkyo-ku, Tokyo 112

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Date	Title	Site	For information, contact
September (tentative)	The 8th International Congress of Psychosomatic Obstetrics and and Gynecology	Melbourne, Australia	Dr. L. Dennerstein Department of Psychiatry University of Melbourne c/o Royal Melbourne Hospital Parkville, Melbourne 3052
Undecided	International Microbiological Congress	Perth, Australia	Australian Academy of Science P.O. Box 783 Canberra, A.C.T. 2601

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1983-426-681

NOTICE

The Office of Naval Research Scientific Liaison Group, Tokyo was disestablished on 30 September 1981. Effective 1 October 1981, the Office of Naval Research, Liaison Office, Far East (ONRFE) has been established as a tenant of the Akasaka Press Center, Tokyo. The ONRFE office is located on the second floor of Bldg #1, Akasaka Press Center and it bears the following mail identification:

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